

# Strategic Decision Analysis for Transportation Systems

by

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Submitted to the Department of Civil and Environmental Engineering  
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## **Abstract**

This thesis examines decision analysis methods of capital investment in transportation systems. The transportation system is a fundamental infrastructure, and requires strategic thinking in making decisions on its projects. The current valuation methods, however, do not reflect the strategic value of a project. We investigate how to make a strategic decision by comprehensively valuing a project in transportation systems.

This study begins by analyzing the characteristics and risks of a railway project as an example of the transportation system, and comparing the current valuation methods based on this analysis. Current methods are useful in valuing a project when we can fairly predict its performance in the system. However, we have difficulty in valuing a project under uncertainty. Focusing on the present value of cash flows does not properly measure the significance of a strategic project, but real options value (ROV) is an effective tool to do it.

We next examine the theoretical correctness of the real options as applied to a transportation project. The critical question is whether we can create a portfolio that replicates the payoffs of options even if we cannot trade the options in a market. We answer this question by proposing the complete market assumption in the real options.

To this end, we analyze a case of a railway project with Binominal Model. ROV quantifies the strategic value of a project, and consequently improves the investment strategy. We show how it is critical to recognize options in a project and benefit from them to effectively develop transportation systems in a competitive market.

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## Table of Contents

<b>ABSTRACT</b>	<b>3</b>
<b>ACKNOWLEDGMENTS</b>	<b>5</b>
<b>TABLE OF CONTENTS</b>	<b>6</b>
<b>LIST OF FIGURES</b>	<b>8</b>
<b>LIST OF TABLES</b>	<b>9</b>
<b><u>CHAPTER 1 INTRODUCTION</u></b>	<b><u>10</u></b>
<b>1.1 OVERVIEW</b>	<b>10</b>
1.1.1 HISTORICAL BACKGROUND	10
1.1.2 MOTIVATION AND OBJECTIVES	11
1.1.3 STRUCTURE	13
<b>1.2 RAILWAY PROJECT</b>	<b>15</b>
1.2.1 FUNDAMENTAL FUNCTION OF “RAIL”	15
1.2.2 MARKET FORCE	16
1.2.3 BUSINESS DYNAMICS	20
1.2.4 CAPITAL INVESTMENT	22
<b>1.3 RISK AND UNCERTAINTY</b>	<b>24</b>
1.3.1 RISK	24
1.3.2 STRATEGY	27
1.3.3 UNCERTAINTY	29
<b><u>CHAPTER 2 DECISION ANALYSIS</u></b>	<b><u>33</u></b>
<b>2.1 LITERATURE REVIEW</b>	<b>33</b>
2.1.1 NET PRESENT VALUE	34
2.1.2 CAPITAL ASSET PRICING MODEL	36
2.1.3 SENSITIVITY ANALYSIS	38
2.1.4 MONTE CARLO SIMULATION	39
2.1.5 DECISION TREE	41
<b>2.2 IMPLICATIONS</b>	<b>43</b>
2.2.1 EFFECTIVENESS	43
2.2.2 LIMITATIONS OF NPV	45
2.2.3 OPTION APPROACH	47
<b>2.3 PROPOSED STRATEGY</b>	<b>48</b>
2.3.1 FLEXIBILITY	49
2.3.2 TIMING	49
2.3.3 VALUATION	50

---

**CHAPTER 3    REAL OPTIONS**

---

**52**

<b>3.1 THEORETICAL BACKGROUND</b>	<b>52</b>
3.1.1 PROJECT AND OPTIONS	52
3.1.2 VALUE OF OPTIONS	53
3.1.3 NO-ARBITRAGE APPROACH	56
3.1.4 COMPLETE MARKET ASSUMPTION	58
<b>3.2 APPLICATION TO RAILWAY PROJECTS</b>	<b>63</b>
3.2.1 EXPANSION OPTION	63
3.2.2 ABANDON OPTION	65
3.2.3 WAIT OPTION	66
3.2.4 SWITCH OPTION	68
<b>3.3 VALUATION FRAMEWORK</b>	<b>69</b>
3.3.1 BLACK-SCHOLES FORMULA	70
3.3.2 BINOMINAL MODEL	71

---

**CHAPTER 4    CASE STUDY -STATION DEVELOPMENT-**

---

**75**

<b>4.1 CASE DESCRIPTION</b>	<b>76</b>
4.1.1 COMPANY INFORMATION	76
4.1.2 STATION DEVELOPMENT PROJECTS	79
4.1.3 NPV ANALYSIS	84
<b>4.2 REAL OPTIONS ANALYSIS</b>	<b>90</b>
4.2.1 RESULTS OF THE NPV ANALYSIS	90
4.2.2 VALUATION PROCESS	92
4.2.3 OPTIONS VALUE	97
<b>4.3 RECOMMENDATIONS</b>	<b>106</b>

---

**CHAPTER 5    CONCLUSION**

---

**111**

<b>5.1 CONCLUSIONS</b>	<b>111</b>
<b>5.2 FUTURE RESEARCH</b>	<b>114</b>

<b>BIBLIOGRAPHY</b>	<b>117</b>
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## List of Figures

FIGURE 1-1 THE FIVE COMPETITIVE FORCES THAT DETERMINE INDUSTRY PROFITABILITY .....	17
FIGURE 1-2 TWO DIFFERENT LOOPS OF INVESTMENT EFFECTS.....	21
FIGURE 1-3 PORTFOLIO OF PROJECTS IN A RAILWAY COMPANY (EXAMPLE).....	23
FIGURE 1-4 MANAGING RISKS .....	28
FIGURE 1-5 DIFFERENT RISK .....	30
FIGURE 1-6 DIFFERENT UNCERTAINTY .....	30
FIGURE 1-7 GEOMETRIC BROWNIAN MOTION MODEL.....	31
FIGURE 2-1 A FIRM CAN EITHER INVEST THE CASH IN A PROJECT OR RETURN IT TO SHAREHOLDERS.....	35
FIGURE 2-2 CAPITAL ASSET PRICING MODEL .....	37
FIGURE 2-3 EXAMPLE OF THE RESULT FROM MONTE CARLO SIMULATION .....	40
FIGURE 2-4 EXAMPLE OF DECISION TREE .....	42
FIGURE 2-5 VALUATION FRAMEWORK.....	45
FIGURE 2-6 VALUE OF A PROJECT IN DIFFERENT APPROACHES UNDER THE UNCERTAINTY .....	48
FIGURE 3-1 VALUE OF OPTION (CALL OPTION) .....	54
FIGURE 3-2 ASYMMETRICAL DISTRIBUTION GIVES VALUES TO OPTIONS .....	66
FIGURE 3-3 EXPECTED VALUE OF OPTION .....	73
FIGURE 4-1 OPERATING AREA OF JR EAST .....	77
FIGURE 4-2 EXAMPLES OF THE STATION DEVELOPMENT.....	79
FIGURE 4-3 RANKING AND LOCATION OF PROJECTS A, B, C.....	81
FIGURE 4-4 CONSTRUCTION AND BUSINESS PLAN OF PROJECT A .....	82
FIGURE 4-5 CONSTRUCTION AND BUSINESS PLAN OF PROJECT B.....	83
FIGURE 4-6 CONSTRUCTION AND BUSINESS PLAN OF PROJECT C.....	84
FIGURE 4-7 MINIMUM LEVEL OF CASH FLOW .....	86
FIGURE 4-8 NPV OF PROJECT A, B, C (WITHOUT SALVAGE VALUE) .....	87
FIGURE 4-9 NEW NPV ANALYSIS (WITH SALVAGE VALUES IN PROJECT A AND B) .....	88
FIGURE 4-10 IMPLEMENT STRATEGY .....	92
FIGURE 4-11 UNCERTAINTY WILL DECREASE AS THE INVESTMENT PROCEEDS .....	94
FIGURE 4-12 VOLATILITY OF THE UNDERLYING ASSET.....	96
FIGURE 4-13 VOLATILITY IN THE SALES PER UNIT AREA.....	96
FIGURE 4-14 FLOW CHART FOR THE DECISION PROCESS IN EXERCISING OPTIONS .....	100
FIGURE 4-15 EXERCISE TIMING.....	101
FIGURE 4-16 VALUE OF THE PROJECTS (A, B, C) BY IMPLEMENTATION STRATEGIES .....	107
FIGURE 4-17 MANAGERS CAN CHOOSE EITHER SPEED OR CASH VALUES IN AN IMPLEMENT STRATEGY .....	108
FIGURE 4-18 ADDITIONAL VALUES OF PROJECTS .....	109
FIGURE 5-1 NETWORK FACTOR.....	114

## List of Tables

TABLE 1-1 DIFFERENT RANGES OF COMPETITION .....	18
TABLE 1-2 ATTRACTIVENESS OF THE RAILWAY MARKET .....	19
TABLE 3-1 RELATIONSHIP BETWEEN THE OPTION VALUE AND EACH PARAMETER .....	55
TABLE 3-2 THREE STRATEGIES FOR INVESTMENT IN A RISKY ASSET .....	57
TABLE 4-1 FINANCIAL HIGHLIGHTS IN THE FY 2001 (MILLION DOLLARS).....	78
TABLE 4-2 PROJECT DATA.....	82
TABLE 4-3 SPREADSHEETS FOR THE NPVS OF PROJECT A, B, C (\$M).....	89
TABLE 4-4 RESULTS OF ROV ANALYSIS .....	97
TABLE 4-5 PARAMETERS .....	98
TABLE 4-6 BINOMINAL MODEL OF PROJECT A (PERIOD 0-1).....	100
TABLE 4-7 OPTION PRICING FOR PROJECT A.....	102
TABLE 4-8 OPTION PRICING FOR PROJECT B.....	104

# **Chapter 1 Introduction**

## **1.1 Overview**

### **1.1.1 Historical Background**

The transportation system is a fundamental infrastructure, which supports our daily life, economic activities, and the future development of society. Throughout the history of our nation, we have developed a wide variety of transportation systems with the combined effort of the public and private sectors. Among them, the railway system, which was born in the beginning of the 19<sup>th</sup> century, was one of the greatest innovations of the industrial revolution both in terms of technology and management, and has contributed to the development of the transportation industry all over the world.

The railway has a competitive advantage in its efficiency. It can carry a large number of passengers and freight at a good speed with relatively lower cost and less consumption of energy than other modes. In the process of industrialization, we have developed railway-specialized infrastructures, such as inter-city (sometimes international) connections and commuter systems in metropolitan areas. The railway network is a quite important element for urban planning and public policy, and can be an excellent business model as a profit-based company. When we review the history of the U.S., the railway used to be one of the profitable industries in the 19<sup>th</sup> century. In other countries, we can also see that venture investors founded many railway companies.

Since the middle of the 20<sup>th</sup> century, however, many railway businesses have declined with the emergence of motorization and air transportation. Some ended in bankruptcy; others survived while receiving subsidies from the government. The railway is no longer an attractive business in some countries. Of course, private ownership is not always the best form for railway organizations, and public ownership and management can be appropriate in given situations. Still, we recognize the significance of privatization, which is currently evolving all over the world, and how private management and business strategy are effective in improving the value of the infrastructure. We are concerned with how we can revive the railway business in the 21<sup>st</sup> century.

### **1.1.2 Motivation and Objectives**

Why has the railway business declined? Was it just because of the competition with automobiles, trucks, or airplanes? Are railway companies profitable only if they have monopoly power in the transportation market? We can say that the railway used to dominate the transportation market, but lost its share to automobiles, trucks, and air transportations. The railway business is, however, still profitable in some segments. For instance, freight railways in the U.S. keep high market share and reasonable profit, and commuter railways in the Tokyo metropolitan area have developed diversified business models. Moreover, high-speed railways in Europe, which are partly subsidized, have captured some demand for travel/business trips again, and demonstrated the potential success of the business if a railway company could match their service and fare to market needs.

A primary reason for failures in the railway business is that managers could not make strategic decisions about how to adjust to their new business environments. This is not saying that it was the manager's fault, but clarifies how difficult it is to determine strategies in a large and complex system such as the railway. Managing a transportation project is difficult because each project does not work individually; rather, it performs as a part of system. Making decisions in a project may give unexpected impacts on another project in the complex system. Sussman (2000) advocated, "*Transportation is an example of a broader class of systems we call CLIOS - complex, large, integrated open systems*"<sup>1</sup>. This fundamental nature of the transportation as a system makes it challenging for managers to predict the performance and impacts of a project, and, thus, determine their strategy. Therefore, there are recent advances in technologies, logistics, and management to support decision analysis for transportation systems.

Standing on these accomplishments, this thesis investigates how we can develop a methodology that can be applied to strategic decision analysis for transportation systems by taking advantage of recently advanced management theories. Specifically, we will focus on quantitative approaches to an optimal investment strategy of a railway company over time. The practical objective of this research is to improve the decision-making process for investment of railway projects, and enhance the competitiveness of railway companies in the transportation market.

---

<sup>1</sup> Sussman, Joseph "Introduction to Transportation Systems", 2000, pp. 6-7



### 1.1.3 Structure

This thesis mainly focuses on methodologies for decision analysis of a transportation project. In particular, we examine which method is effective for different types of projects, what will be the problems in applying it, and how to adjust these methods for a project. As an application, we study a railway project case to confirm the effectiveness of these methodologies in making strategic decisions in a large and complex transportation system.

In Chapter 1, we summarize the characteristics and risks of a railway project, which have impacts on decision-making process. In a transportation project, many studies have been done to forecast the demand, design an effective investment, and evaluate the feasibility so that we can deal with “risk”, which can be quantified by a probabilistic approach. However, we still have difficulty in dealing with “uncertainty”, in which the probabilities of potential outcomes are unclear. Therefore, managers periodically review their projects; this can be a practical way to cope with the uncertainty. However, most infrastructure investment is irreversible, so we need to recognize this uncertainty even in the decision-making process. This chapter specifies the target for strategic decision analysis, which we develop in this research.

Chapter 2 first reviews current literature for decision analysis theories, and next compares their effectiveness in terms of application to a railway project. Among them, Net Present Value (NPV) seems to be a current paradigm for many companies in making decisions on capital investment. This methodology, however, heavily depends on the projected cash

flows, and is quite sensitive to unexpected events. Theoretically, the NPV can consider the risk of a project, but has difficulty in fully dealing with uncertainty. This chapter introduces a concept of “real options” which can value a project under uncertainty by taking advantage of recently developed financial option techniques.

We examine the details of real options in Chapter 3. The key idea is “options” in the decision-making process. If the future is difficult to predict, it is better to provide some flexibility in a project than make every decision in advance. Using the real options, we can value the flexibility and allow managers to decide when they implement each investment over time and with new information. This chapter suggests how we can utilize real options for a specific type of railway projects.

In Chapter 4, we analyze a strategy of station development projects as a case study. This case describes a strategic decision of East Japan Railway Company (Tokyo, Japan) who explores business opportunities by developing the stations in the Tokyo metropolitan area. The company recognizes the potential advantage of stations, which are located at the centers of downtowns and have many passengers. The managers, however, have difficulty in making an investment decision by using the NPV, which does not reflect the strategic value of this project. We examine how real options provide a rational answer for this decision-making problem.

Chapter 5 concludes this thesis by summarizing the results of this research and proposing further research to expand the application of real options in transportation systems.

## **1.2 Railway Project**

This chapter introduces fundamental concepts of a railway project. We summarize railway-specific characteristics and classify projects to explain the focus of the strategic decision analysis. This process provides the basis of arguments in the following chapters.

### **1.2.1 Fundamental Function of “Rail”**

The definition of railway can be that it has “rail” in its system components. The existence of rail has two significant meanings when we discuss its characteristics. One is the advantage of “efficiency” both in terms of technology and management. The other is the disadvantage of “rigidity” due to its fixed cost and fixed location of the facilities.

The use of steel rail and wheel drastically decreases the physical friction and loss of energy compared to other surface transportation systems. Combined with the invention of internal-combustion engine, the railway gave us the ability to transport a large number of passengers and freight with low cost and high speed. The fixed route enables us to operate the vehicles efficiently. Using advanced signal and control technologies, we can realize high transport density. The minimal impact of the railway on the environment is also derived from its efficient consumption of energy in this system.

The fixed cost and fixed location of facility, on the other hand, is the major disadvantage of rail systems. Vehicles have to operate on the rail, and cannot freely choose their route, unlike automobiles or trucks. Therefore, the railway requires a certain amount of facilities

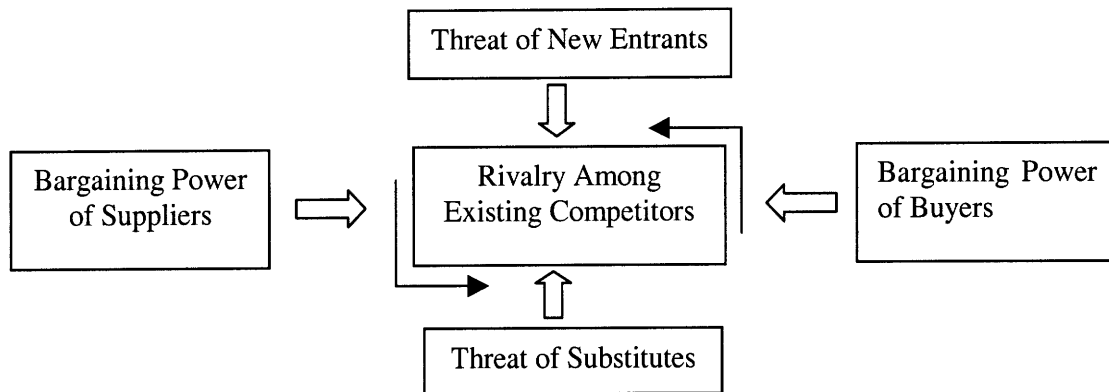
regardless of the level of demand and operation density. In a certain situation, fixed facilities cost more than the operating cost, and, sometimes, more than the revenue. We continue to discuss further aspects of a railway project, which affect decision analysis, but this fundamental tradeoff is the basis of these arguments.

### **1.2.2 Market Force**

Porter (1998) explains the long-term profitability of a firm based on the five forces in the market value chain. Figure 1-1 describes how the combination of these five forces will determine the dynamics of competition, and how a firm will assess its position in a competitive market.

Porter's model explains the demand from the market, which puts pressure upon each firm's performance. Every firm has to improve its service (product) while raising the quality and lowering the cost throughout the market value chain. The firm is exposed to direct competition with its rivals to keep/increase its share in an existing market segment (rivalry among existing competitors). If the market segment is attractive enough, another rival, who is not currently a competitor, will come in to try to take the customers away (threat of new entrance). The firm needs to compete with existing rivals while building the entry barriers against potential competitors. In addition, the firm has to compete with another market segment such as new products or services which can replace theirs (threat of substitutes). Customers are often in a position to choose from competitors or negotiate

the price (the bargaining power of buyers). The firm's suppliers also put pressure on the firm's strategy to improve their inbound logistics (the bargaining power of supplier).

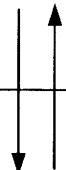


**Figure 1-1 The Five Competitive Forces that Determine Industry Profitability <sup>2</sup>.**

The nature of the railway business, however, makes it difficult for managers to fully deal with these five forces. As described in this chapter (1.2.1 Fundamental Function of Rail), the railway system needs fixed facilities to achieve its low operating cost. This fact naturally results in economies of scale, which resulted in a regional monopoly in some cases. Therefore, a railway company does not always have severe competition directly with other railway companies. Vast initial investment, government regulation, and the potential advantage of a predecessor imply high entry barriers to potential competitors. However, other transportation modes (e.g., auto, air, truck) can eventually take their customers away as substitutes. This is actually what happened in the 20<sup>th</sup> century. Also,

other communication methods such as the telephone or Internet can be effective substitutes for this market in a long time scale. Moreover, we can consider the customer's preference in spending time as a substitute for this segment (e.g., customers may prefer staying home to traveling). These different ranges of competition add complexity for managers as to their market position. Table 1-1 summarizes these different ranges of competition. It is easy for managers to recognize direct competitors (1<sup>st</sup> range) and take measure to cope with the situation. Indirect competition (2<sup>nd</sup>-4<sup>th</sup> range) proceeds in relatively long time-scales, and thus it is difficult to determine the market position if managers focus on short-term performance. The railway business often faces these indirect competitors more than direct ones, and managers are required to strategically compete with these various rivals in different time scales.

**Table 1-1 Different ranges of competition**

Range	Competitor	Time Scale	Driver
1 <sup>st</sup>	Other railway companies	Short	Level of Service Availability
2 <sup>nd</sup>	Other transportation modes		Infrastructure Purpose of trip
3 <sup>rd</sup>	Communication technologies		Technological innovation Business style
4 <sup>th</sup>	Preference in spending time	Long	Attractiveness Sense of value Family structure

---

<sup>2</sup> Porter, Michael E., "Competitive Advantage", The Free Press, 1998, pp. 5

Furthermore, customers usually have little bargaining power against providers in terms of price. They can choose a transportation mode based on the level of service of their options. Customers are, however, rarely in the position to deal with the price or service individually. This bargaining power is exercised by the government as a regulator. Managers sometimes misunderstand who the customer is for their service. Some railway companies are not customer-oriented, but government-oriented. The supplier sometimes has strong bargaining power when the entry barrier (e.g., railway-specific standard) discourages the new entries in the inbound industries, and decreases the number of competitors. In this case, the supplier may have monopoly power, which prevents the improvement of inbound logistics and technical innovations of a railway company. We can also include labor union issues in this category of suppliers. Table 1-2 summarizes the long-term attractiveness of this market.

**Table 1-2 Attractiveness of the railway market**

Market Force	Threat	Factors
Rivalry Among Existing Competitors	Low	Economies of Scale
Threat of New Entrants	Low	Vast initial investment Regulation
Threat of Substitutes	High (Gradually)	Other transportation modes Communication technologies Preference in spending time
Bargaining Power of Buyers	Middle	Customer – Low Government – High
Bargaining Power of Suppliers	Middle	Manufacturers Labor unions

(Note: Low level of threat = High profitability of the market)

### 1.2.3 Business Dynamics

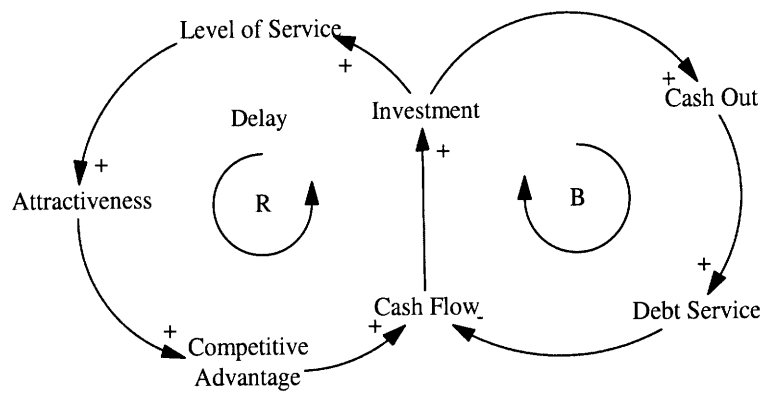
Managers have to deal with these market forces in a railway business. The complex system and business environment of a railway company, however, may lead managers to improper decisions. Although their principal goal is to create and maintain a competitive advantage in the market, managers tend to insist on short-term profits and operation policies due to the different time scales of their system output. For example, safety and environment related investment does not provide direct financial returns, unlike more frequent operation or high-speed projects. These projects pay, however, in the long run through the improvement of their reliability in service and healthy development of the land use or community. The lack of direct competitors may lead managers to save the capital investment and maintenance expenditure, which lower their competitiveness in the future. Also, managers have to optimize their strategy in different time scales. Since most infrastructure investment is usually irreversible, the optimal design of a project in a short term may have negative impacts on the potential opportunities in the future.

Sterman (2000) built system thinking and a modeling framework for a complex world, arguing that our own actions have unanticipated side effects and cause many problems in the future<sup>3</sup>. Therefore, our effort to solve important problems may not only fail but also make it worse or create new problems. To deal with the growing dynamic complexity, we need to expand the boundaries of our mental model and develop strategic thinking in the decision-making process.

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<sup>3</sup> Sterman, John D., "Business Dynamics", Irwin McGraw-Hill, 2000





**Figure 1-2 Two different loops of investment effects<sup>4</sup>**

Figure 1-2 indicates two different loops of investment effects in a firm. The right loop shows a short-term effect of the investment on the financial status. The incremental investment will increase the cash out, and debt payment, and finally decrease the source of investment (cash flow). This loop works to balance (B) the financial status through investment activities. The left loop indicates how the investment gives returns through the sequential increase of the level of service, attractiveness, and competitive advantage, and cash flow. This loop works to reinforce (R) the investment direction in both positive and passive ways. The point is that these two loops work in different time scales. Investment decisions based on the present financial status may result in non-optimal use of capital resources and consequently insufficient investment effects. Managers have to maintain their strategic views in making decisions on investment. Standing still or focusing on short-term return is not a good option in a business.

<sup>4</sup> This diagram is originally drawn for this thesis.

#### **1.2.4 Capital Investment**

We now discuss the types of investment. In general, there are two broad categories in railway investment. One is the operating investment, which sustains the current performance of the system. The other is the capital investment, which has strategic objectives to enhance the performance of the system. This thesis mainly focuses on the capital investment since it is a critical decision, which enables the railway company to strategically compete in a complex environment.

Of course, maintenance can be an incrementally important factor for the management of a railway company. It is, however, a kind of requirement to sustain the current operating performance and the level of service. This can be somewhat adjusted by managers according to the situation, but cannot be drastically changed. Therefore, we will focus on the capital investment in which managers have ability to design their investment.

The capital investment enhances the performance of systems to achieve the goal and mission of a company. This investment is an important management decision. It is a difficult decision not only because it is a large investment, but also because it can carry extra risks to the company. The capital investment is actually productive activity, which tries to increase the value of the company. Its usually irreversible nature and strong impacts on the operation and maintenance activities, however, create additional risks as a result.

Figure 1-3 shows the portfolio of projects in a railway company. The railway company can diversify its portfolio by exploring other business, which has synergistic effects with railway activities (e.g., real estate, hotel, resort). In this thesis, however, we limit the scope of the portfolio to the following major projects (Figure 1-3) so that we can examine the strategy of railway companies. Although every project requires sophisticated decisions on its investment, projects in shaded segments (capital investment) need more strategic thinking to mitigate the risks in this portfolio.

		Risk		
		Low	Middle	High
Scale	Small	Routine Maintenance	Grade-Separation	Rolling Stock
	Middle	Rehabilitation	Safety, Environment	High Speed Rail, Station Development
	Large	Capital Replacement	Modernization	New Line, New Station

**Figure 1-3 Portfolio of projects in a railway company (example)**

## **1.3 Risk and Uncertainty**

In Figure 1-3, we classified railway-specific projects based on their scale and risk. Managers have to recognize the importance of risk assessment to cope with the different levels of risk in their projects. In this section, we identify the risks in a railway project, suggest strategies to cope with the risks, and define the difference between risk and uncertainty to manage a strategic project.

### **1.3.1 Risk**

Lessard and Miller (2001) successfully classified the types of risk faced in large engineering projects, and consolidate them into three major risk categories; (1) Market Risk, (2) Technical Risk, and (3) Institutional Risk. These categories are useful for us in identifying the risks of a railway project. Although the type of risk differs according to a project, these categories are properly applicable to a railway project based on the arguments, which we have made in this chapter. Therefore, we examine the risks based on these categories. However, the risk does not work separately; or rather, it is often accompanied by many related risks, which affect the performance of the project in a complex way. Hence, managers are required to pay comprehensive attention to the risks in order to mitigate and avoid the managerial losses incurred when the some of the risks turn into reality.

## **Market Risk**

The demand, finance, and operations risks are in this category. In a business, the market is always important but uncertain. The profitability of a railway business depends on the demand of the market. This market risk is related to the ability to forecast the demand. Inaccuracy in the forecast may lead to shortfall in the cash flows, or inadequate capacity of facilities. Moreover, in many transportation projects, the demand has a fundamental tradeoff relationship with the level of service. Adjusting the fare to balance the demand may even worsen the situation in a competitive market. In general, demand is very difficult to predict and hence constitutes a great income risk. Also, urban transportation projects, which can expect high demand, face the high cost of projects because of expensive land acquisitions and strict environmental constraints.

On the other hand, operations risk is relatively low for a railway project once it recovers the initial investment. The railway project has reliable daily cash flows from passengers. Moreover, the demand, specifically in the commuter segment, is stable regardless of economics cycles. In addition, the low operating cost of the railway enables it to keep earning cumulative profits through the operating period. In general, the volatility of the market risk is very high in the beginning, and rapidly stabilized through the life of a project.

### **Technical Risk**

The technical risk is mainly related to the complexity of the system. Since a railway project involves many types of different software and hardware, both individual performance of each system and the integration of the whole system can be concerns. In particular, the integration between newly installed technologies and the existing railway system can present a challenge for a railway project. Developing a new technology is based on numerous assumptions that cannot be verified until the operation starts. When we put a new technology to practical use, it may not only fail to perform well, but also it can disorder the correct operations of existing systems. However, due to the social responsibility as an infrastructure, managers are required to keep operating railway systems, and have to avoid such troubles. To launch a new technology or modify an existing system involves complex risk. Managers have to maintain sufficient technological expertise to deal with this complexity.

### **Institutional Risk**

The regulatory and political risks are concerns to a railway project. As an infrastructure, the regulator sometimes has strong authority for providing a permit (concession) to a new railway project. The manager has to consider the regulatory frameworks, urban planning, and public policies surrounding the project in the entry strategy.

The feasibility of a project also depends on the law and regulations that govern the pricing rule, liability, property rights, and contracts of the project. The railway project

faces regulatory and political risks, which may impose unanticipated restrictions on the project. We also have to consider the possibility that a project will meet opposition from the residents, local groups, interest parties, and politicians.

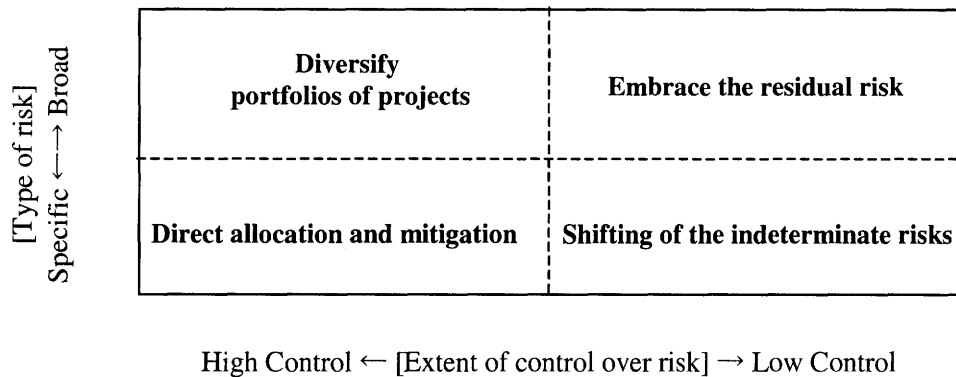
Furthermore, if the expected return from the project is insufficient, and managers have no alternative to increase the return, they usually take an exit strategy. In a railway project, however, it is often difficult to stop providing its service or sell its assets. In this case, the project loses its ability to limit substantial loss, and managers have to cope with this institutional risk even in taking the exit strategy.

### **1.3.2 Strategy**

Lessard and Miller (2001) argue, “*Successful projects are not chosen but shaped with risk resolution in mind.*”<sup>6</sup> This statement implies how it is critical for managers to recognize the risk in advance and prepare proper solutions to mitigate its negative impacts. In order to manage the risk, first of all, we need to identify the investment-related risk. Next, we also need to evaluate their impacts on investment activities. The objective of this process is to reduce the exposure of the investment to the identified risk. Figure 1-4 shows the proposed strategy based on the type and the extent of control over risk.

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<sup>6</sup> Lessard D. & Miller, R., “The Strategic Management of Large Engineering Projects”, MIT Sloan Working Paper, 2000



**Figure 1-4 Managing Risks<sup>7</sup>**

If the risk is specific to a project and controllable, try to identify the source and the impacts of the risk, and reshape the investment so as to allocate and mitigate the negative impacts. This is the basic case in risk management. If the risk is specific to a project but outside the control of managers, however, they have to shift the risk by using contracts or markets and prepare for unexpected events. This can be the risk management on a project level. In contrast, when the risk is broad but controllable, the effective approach is to diversify the portfolio of projects and reduce the impacts of the risk. This approach has to be done not on a project level, but on a corporate level. Finally, when the risk is difficult to specify and control, we have to embrace this risk. Managers have to decide if the risk is worth taking.

<sup>7</sup> Lessard D. & Miller, R., "Understanding and Managing Risks in Large Engineering Projects", 2001 p.11



### 1.3.3 Uncertainty

In this thesis, we have been using “risk” to consider the possible impact of unexpected events in a project. In order to practically manage a project, however, we have to distinguish “uncertainty” from “risk”, and recognize the different natures and effects of the two states.

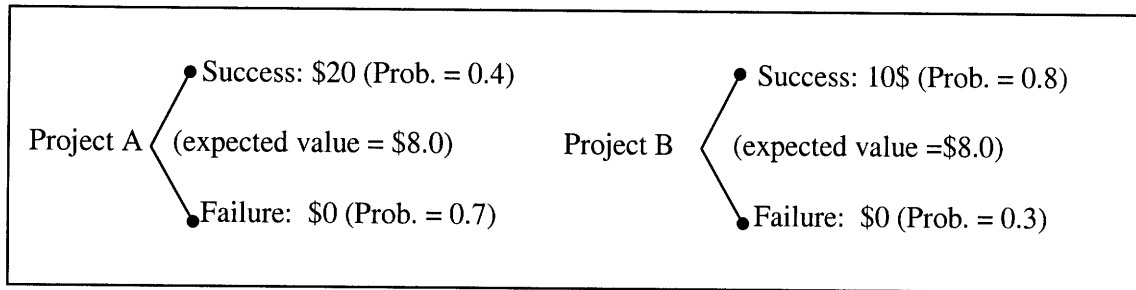
Lessard and Miller (2000) explained risk as “*the possibility that events, the resulting impacts, the associated actions, and the dynamic interactions among the three may turn out differently than anticipated.*”<sup>8</sup> Here, we understand that risk can be quantified in statistical terms, and we can take a probabilistic approach to cope with unexpected events. However, “*uncertainty characterizes situations in which potential outcomes are not fully understood.*” The common concern are unexpected events in the future, which impacts on a project, but the difference is whether we can estimate the probabilities of the unexpected events. To make the difference clear, we define the risk and uncertainty in the following manner:

Risk: The possibility of unexpected events with knowable probabilities, and considering the impact of various events.

Uncertainty: The distribution of possible outcomes with unclear probabilities.

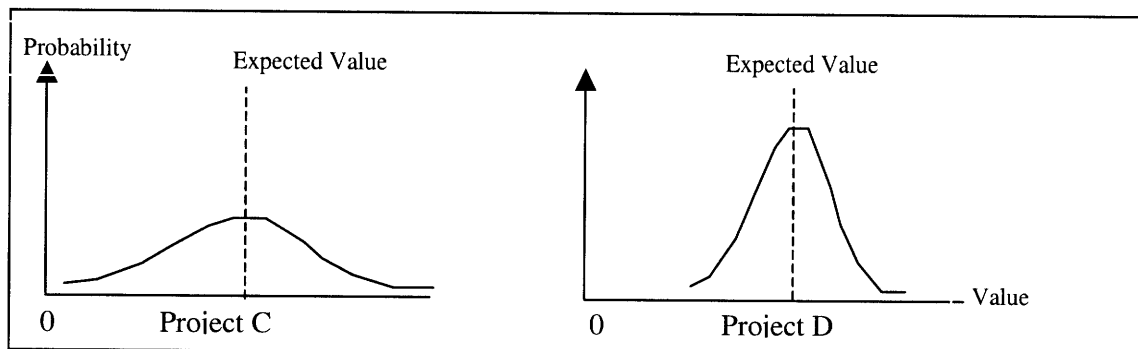
[Note: We use “risk” when we simply consider the possible impact of unexpected events without distinguishing the probability issue (e.g., 1.3.1-2)]

For instance, Figure 1-5 shows two projects, which have different risks. Although both projects have the same expected value, project A has higher risk since it is more likely to fail. Probability matters in risk analysis, and we can decide whether we will accept the risk or not based on the expected value of a project, the probabilities of possible outcomes, and our risk preferences.



**Figure 1-5 Different Risk**

However, we do not always understand the clear probabilities of events, and have to consider uncertainty in a project. Figure 1-6 indicates two projects, which have different uncertainty. Both projects have the same expected value, but project C is more uncertain because it has more volatility. We have to consider the range of the possible outcomes, and volatility matters in dealing with uncertainty.



**Figure 1-6 Different Uncertainty**

<sup>8</sup> Lessard, D. & Miller, R., "The Strategic Management of Large Engineering Projects", MIT Sloan Working Paper, 2000

The Geometric Brownian Motions Model, which is frequently applied to describe the movement of financial variables (e.g., stock price, interest rate), expresses the significant difference between risk and uncertainty in its diffusion process. According to this model, the value of a financial asset evolves based on the following formula:

The Brownian Motions Model:

$$dV = \alpha \cdot V \cdot dt + \sigma \cdot V \cdot dz$$

Where:

$V$ : Value of a financial asset

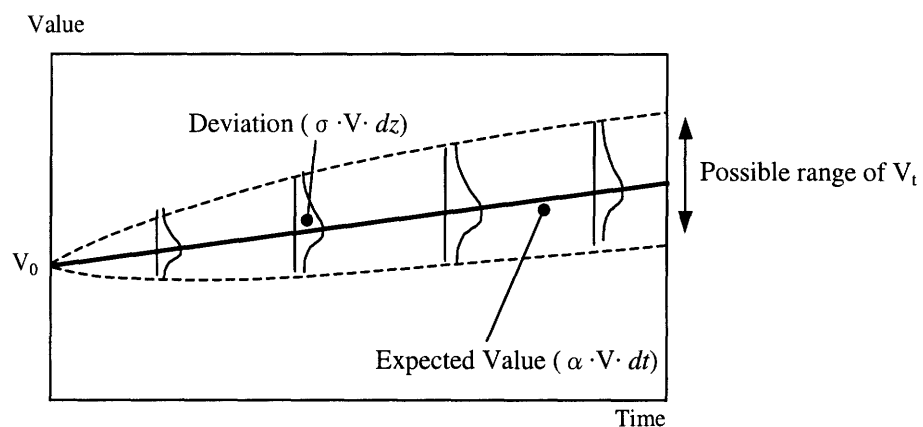
$\alpha$  : Expected annual growth rate

$dt$ : Time interval

$\sigma$  : Standard deviation of  $V$

$dz$ : increment of standard Wiener process<sup>9</sup> ( $= \epsilon \cdot \sqrt{dt}$ )

$\epsilon$ : normally distributed random variables with zero mean and a standard deviation of 1.0



**Figure 1-7 Geometric Brownian Motion Model**

<sup>9</sup> The Wiener process describes a random motion of a variable.

In this model, the value of an asset varies based on the expected value and deviation on the time axis. Therefore, we have to analyze the risks of an asset to estimate its growth rate and expected value. However, the deviation from expected values also increases, so we have to consider the possible error of the estimation. This deviation indicates uncertainty of an asset where the probability of the movements is unclear.

This difference between risk and uncertainty is critical in choosing an appropriate valuation method in a project. Some methods can take a probabilistic approach to cope with risk. Uncertainty, however, requires managers to take a different approach, and imposes an ambiguous task. We have to keep this fundamental difference in mind, and take an effective strategy based on the characteristics of a project and availability of information. In Chapter 2, we are going to examine the effectiveness of decision analysis methods to value a project under these conditions, and discuss how we can determine investment strategies for transportation systems.

## **Chapter 2 Decision Analysis**

We summarized the characteristics of a railway project and identified its associated risks in Chapter 1. That was the first step in developing an investment strategy for a railway company. What we have to do next is to examine the effectiveness of decision analysis methods to value a project under these conditions. Managers need to evaluate their investment in terms of its impacts on the business activities. Eventually, managers try to reduce the exposure of their projects to the identified risks, and conclude with a certain benchmark for their investment decision-making. Since there is no definitive measure for valuing a project, we have to understand the effectiveness and limitation of each valuation methodology, and use the effective methods according to the nature of a project.

### **2.1 Literature Review**

Among the various project valuation methods, Net Present Value (NPV) seems to be a current paradigm for many companies in making decisions on capital investment. Brealey and Myers (2000) successfully verified the theoretical correctness of NPV and its overall superiority to other valuation methods of a project (e.g., Pay Back Period, Internal Rate of Return) in the finance literature<sup>10</sup>. In this section, we review the NPV, its practical drawbacks, and its applications, which are currently taken to support an investment decision-making.

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<sup>10</sup> Brealey, Richard A. & Myers, Stewart C., "Principle of Corporate Finance", Irwin McGraw-Hill, 2000, pp 93-114

### 2.1.1 Net Present Value

The Net Present Value of a project is

$$NPV = \sum_{t=1}^T CF_t / (1+r)^t - I_0 + S_T / (1+r)^T$$

where:

$CF_t$ : expected cash flows of a project at time “t”

$r$ : the discounted rate reflecting the cost of capital and the associated risks

$I_0$ : initial investment

$T$ : Economic life of a project.

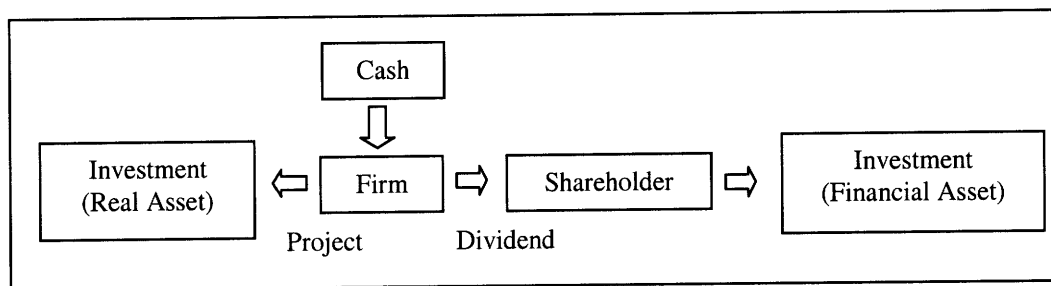
$S_T$ : Salvage value of a project (if applicable)

The NPV will be calculated by:

1. Forecasting the cash flows generated by the project over its economic life.
2. Determining the appropriate opportunity cost of capital, which reflects both the time value of money and risks involved in the project.
3. Using this opportunity cost of capital to discount the future cash flows.
4. Subtracting the initial investment from the sum of the discounted cash flows (present value), and adding the salvage value if the asset has cash value at the end of a project.

If the  $NPV > 0$ , the investment financially makes sense.

The excellence of NPV is its reflection of the investor's expectations. Paying dividends to shareholders is always a firm's alternative to investing in a project. If the expected return from a project is lower than the investor's expectations ( $NPV < 0$ ), a firm can pay dividends to its shareholders, who are also looking for another opportunity in the market.



**Figure 2-1 A firm can either invest the cash in a project or return it to shareholders<sup>11</sup>**

Some criteria such as Benefit/Cost (B/C) and Internal Rate of Return (IRR) can be used with NPV, so as to compare the values of projects, and decide which project to choose. However, these criteria have the same theoretical background of NPV, which focuses on the cash flows and time value of money. Therefore, we categorize them in the same group in terms of a valuation method.

There are, however, two major drawbacks in using the NPV as a valuation method for a project. One is the difficulty of determining an appropriate discount rate, and the other is the ambiguity as to the future cash flows. We review the discount rate problem in 2.1.2 (Capital Asset Pricing Model), and the future cash flows issue in 2.1.3-5 (Sensitivity Analysis-Decision Tree) in order to examine whether we can avoid these drawbacks.

<sup>11</sup> Brealey, Richard A. & Myers, Stewart C. "Principle of Corporate Finance", Irwin McGraw-Hill, 2000, pp 95

### 2.1.2 Capital Asset Pricing Model

In the NPV, theoretically, a discount rate depends on the risk of a project. Using Weighted Average Cost of Capital (WACC) as a discount rate, we can evaluate the risk of a project based on the firm's evaluation in the security market. In this case, there is an assumption that the project's risk is the same as the firm's average risk.

The Weighted Average Cost of Capital of a firm is

$$\text{WACC} = r_e (e/v) + r_d (d/v)$$

where

$d, e$  = current market value of its debt and equity

$v$  = sum of the debt and equity value ( $d + e$ )

$r_d$  = current rate of its borrowing

$r_e$  = current expected rate of return on its stock (including earning and growth)

The railway company, however, has a wide variety of projects, ranging from small-scale and low-risk projects to large-scale high-risk projects<sup>12</sup>. Therefore, this assumption is theoretically inaccurate and leads managers to a wrong decision. Simple use of the WACC will favor the risky projects, while having bias against less risky projects than the average. Our focus is capital investment, which involves relatively high risks. Therefore, we need to consider these risky cash flows by adjusting the discount rate.

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<sup>12</sup> Figure1-3



The most commonly used method for determining the risk-adjusting discount rates is Capital Asset Pricing Model (CAPM), which shows how we can value the individual risk premium in relation to its covariance to the market by using a simple linear formula.

The Capital Asset Pricing Model is:

$$R = R_f + \beta (K_m - R_f)$$

where

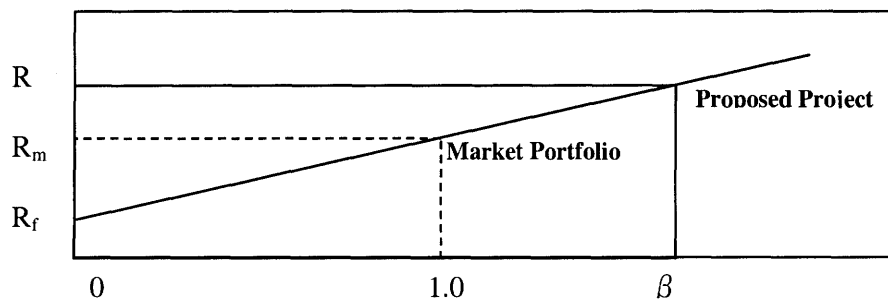
$R$ : expected return rate on a project

$R_f$ : rate of a risk-free investment (e.g., treasury bonds)

$K_m$ : expected return rate for the market portfolio.

$\beta$  : volatility of a project

$\beta$  measures the volatility of a project, relative to the market portfolio. The above equation shows that investors require the higher expected return to compensate the higher expected risk. The formula determines the project-specific risk premium as a linear function of  $\beta$ . Therefore, if we know a project's  $\beta$ , then we know the value of  $R$ , which can be the risk premium for the project.



**Figure 2-2 Capital Asset Pricing Model**

The practical drawback of using the CAPM is how to determine the “ $\beta$ ” for a specific project. Unlike the stock market where the CAPM has been developed, we do not have enough historical data to determine the  $\beta$  for capital investment. Also, historical data from other projects does not correctly reflect the project-specific risks since each project has its unique risks. Using the CAPM gives us insight as to determining the risk premium, but cannot fully solve the discount rate problem.

### **2.1.3 Sensitivity Analysis**

Since the valuation of a project depends on the forecast of its cash flows, we need to examine our premises by changing some critical parameters to see how the NPV will vary according to this change. There are risks associated with the error in the forecast of the initial cost, construction period, revenue, etc. This process provides not only the feasibility of a project in a specific situation, but also the opportunity to re-shape the project based on the sensitivity of each parameter. If the project is very sensitive to a specific parameter, we can try to mitigate the potential risk by modifying the project so as to reduce the exposure to risk.

In practice, managers usually vary input data and model coefficients within a certain range (e.g.,  $\pm 10\%$ ) based on their experience or guidelines. Another simple approach is using the range from “optimistic” case to “pessimistic” case, or taking “reasonable extremes” assumptions to compare outcomes. The underlying concept of this methodology is that more things can happen than will actually happen, and we need to

examine each possibility in dealing with uncertainty. This sensitive analysis helps managers to identify the possible range of outcomes, consider the impacts, and make decisions on investment.

On the other hand, the result is ambiguous. Since the adjustment range is wide, and possible combinations of the sensitive analysis are many, managers often have difficulty finding the rationality of their decisions. In addition, the interrelation among parameters often makes this analysis too complex to use in practice. Furthermore, each situation does not equally happen, but the sensitivity analysis simply shows the result of each case, and does not consider the probabilistic distribution of the outcomes in the simulations.

#### **2.1.4 Monte Carlo Simulation**

The sensitivity analysis enables managers to consider the effect of changing one parameter or limited number of combinations of data at a time. Using Monte Carlo simulation, however, we can consider all plausible combinations of data, and examine the entire distribution of possible outcomes. We simulate a project in a computer by using the assumed distribution of each variable.

In the Monte Carlo simulation, we first have to build a model of the project. This model requires a set of equations and constraints for each of the variables. Second, we have to determine the distribution of our forecast error in each variable. The forecast error has an expected value of zero, and a range of a certain percent (not always symmetric). Finally,

the computer samples from the distribution, and calculates the resulting cash flows (probabilistic distribution of outcomes) as shown in Figure 2-3.

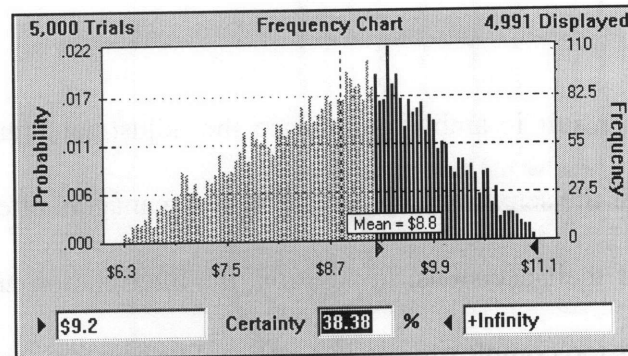


Figure 2-3 Example of the result from Monte Carlo simulation<sup>13</sup>

The advantage of using the Monte Carlo simulation is to allow managers to acknowledge the uncertainty of their project. The manager can gain a better understanding as to how uncertainty financially impacts on their project.

However, the Monte Carlo simulation has some drawbacks. The first one is the modeling problem. It is difficult to determine the model of a project with the interrelationships and probabilistic distributions for each variable. Since the result depends on these assumptions, it is possible that the result will be biased. Also, in practice, a simulation model that tries to be completely realistic will be too complex. Managers have to validate the models to verify the result of simulations, but may have difficulties in fully understanding the meanings of a complex model. The second drawback is the interpretation of the outcomes due to the lack of specific benchmarks. We can use the

<sup>13</sup> <http://www.decisioneering.com/spotlight/>

Monte Carlo simulation to understand the possible distribution of outcomes, but it may be difficult to use it for a decision-making if these drawbacks are critical for managers.

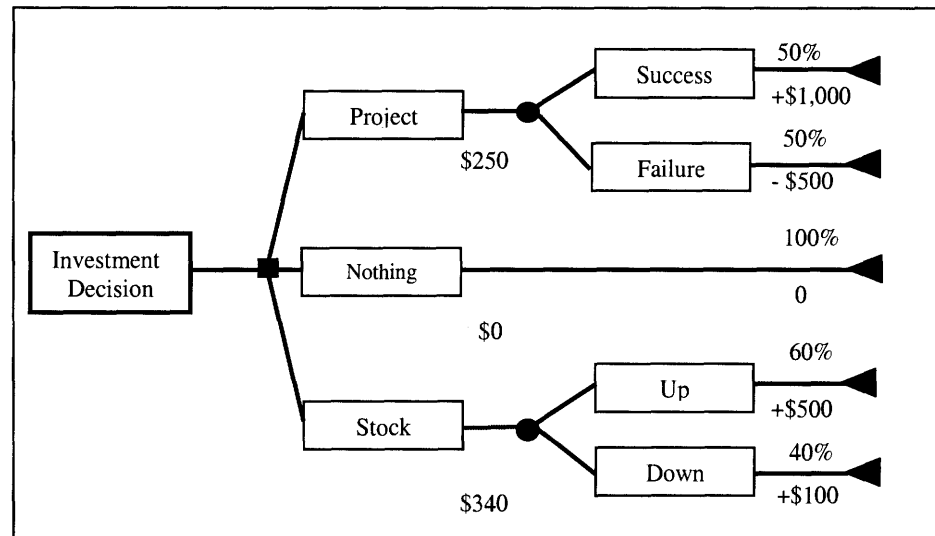
### **2.1.5 Decision Tree**

Both the sensitivity analysis and Monte Carlo simulation provide managers with an understanding of the nature of a project, specifically the possible range and distribution of outcomes. These methods tend to underestimate, however, the value of a project because they do not consider the manager's ability to cope with unexpected events during the life of a project. If the project environment (e.g., market demand) is different from the initial assumption, managers usually abandon the project to limit their loss (in case of bad events), or chose an expansion strategy to increase the benefit (in case of new opportunities). An investment decisions is not simply an accepted/rejected decision that has to be done at the beginning of the project. In reality, subsequent decisions are tied together during the entire period of a project. In this sense, Decision Tree (DT) can be an effective tool to analyze a project that involves sequential decisions.

In Figure 2-4, the square represents the decision point where managers have to choose what to do, while each circle represents probability points where the decision faces different outcomes. The key idea is the combination of the decision and probability points. One decision will reveal the consequential events. Managers can see what will happen, and make decisions at the next step. The DT can make the underlying scenarios clear by

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showing the links between each stage of a project, and help managers to find the strategy with the highest value, which is also the expected value of a project.



**Figure 2-4 Example of Decision Tree**

The DT is particularly useful when we have discrete time stages for information and decisions. Dixit and Pindyck<sup>15</sup> (1994) introduced the continuous version of the DT (dynamic programming), which is available for problems with continuous flow of information and decisions with the same theoretical framework as the DT.

Theoretically, the DT process will turn the possibility into reality, and reduce risk by narrowing the range of potential outcomes. Therefore, we can use a lower discount rate to recognize the change of risks. The DT, however, does not count this value, and uses the

<sup>15</sup> Dixit, A.K. & Pindyck, R.S., "Investment under Uncertainty", Princeton University Press, 1994

same discount rate throughout the life of a project. It simply sums up the cash flows in each scenario as the expected NPV. This assumes that the project's risk is constant regardless of the stage of a project. Another serious drawback is the probability of events. Based on the definition of risk and uncertainty in Chapter 1, we may deal with risk in the DT, but cannot deal with uncertainty, in which the probability of unexpected events is not fully understood.

## **2.2 Implications**

We have reviewed the current decision analysis methods to compare the different approaches in valuing a project. The next step is to categorize these methods so as to specify an appropriate valuation method for a railway project. Since every method has its own advantages and drawbacks, managers cannot simply rely on a single way of valuing a project, and each method should be regarded as a part of the information about the value of a project. Therefore, it is useful to examine the effectiveness of each approach, and examine how we can apply it to a railway project.

### **2.2.1 Effectiveness**

In general, we can summarize the comparison of valuation methods with Figure 2-5. The basic method is the NPV, which reflects the investor's expectations in a project. It is a reliable valuation method if the project is stable and foreseeable in a financial sense. We can use the NPV for a project that has very low risk and uncertainty. Also, the CAPM is a technique to adjust the discount rate of NPV with the project-specific risk. The CAPM

can consider the risk premium on top of the firm's average risk, but has difficulty in dealing with high risk and uncertainty due to the possible error in the forecast of cash flows.

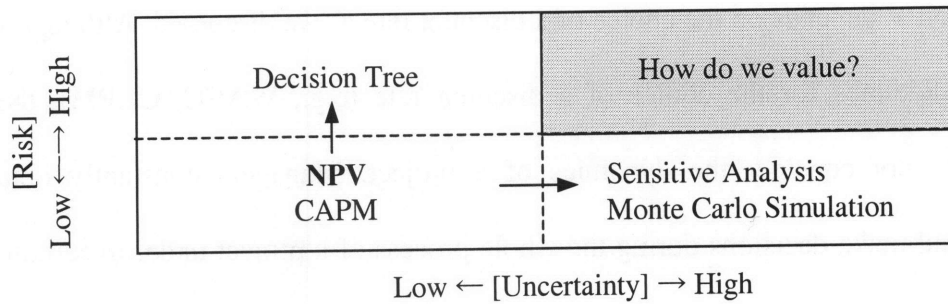
If the risk is high, we can use the DT. We can calculate the expected NPV based on the probabilistic outcomes in the DT. We only have to determine the first step of an investment decision, and make another decision according to the consequential outcomes. Eventually, we can approach the optimal strategy, in which we can expect the highest return from the project. If uncertainty dominates a project and the probability is unclear, we can apply Sensitivity Analysis or Monte Carlo Simulation to consider the potential range and distribution of outcomes.

When we face both high risk and high uncertainty, however, we will be at a loss in dealing with them. Simply combining the above methods is not a good option in this case. Each method has its own practical drawbacks, which may be amplified in combination. In addition, the various criteria confuse managers in dealing with the problems. Furthermore, managers need clear benchmarks for their investment decisions in terms of the accountability to shareholders. The problem we are facing now is critical because capital investments of a railway company<sup>16</sup> typically fit this segment in this matrix. We need to build an additional valuation methodology in addition to these methods.

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<sup>16</sup> Figure 1-3





**Figure 2-5 Valuation Framework**

### 2.2.2 Limitations of NPV

We investigate the effectiveness of NPV again because the above valuation framework is based on the NPV method, and others basically expand the practicality of NPV in dealing with risk and uncertainty. If the NPV has an inevitable limitation when valuating a railway project with the existence of high risk and uncertainty, we have to consider another approach to value a project.

The fundamental assumption of NPV is that money has a time value, and we can measure it by using a discount rate. Here, reliable cash flows are more valuable than risky cash flows. Therefore, risk always gives negative impacts on the valuation of a project through the higher discount rate. The underlying value of a project is always the expected cash flows, which can be adjusted by considering its risk. In practice, the following two reasons highlight why we have difficulty in using the NPV as a valuation method of a railway project where high risk and uncertainty are main concerns.

1. The discount rate is too ambiguous to value a project under uncertainty.

The result of NPV depends on the choice of a discount rate as we discussed. Although we have some guidelines for the choice of a discount rate (e.g., WACC, CAPM), these approaches do not consider the dynamics of a project. Managers constantly obtain information and make decisions during the whole process of a project under uncertainty. Finally, we try to choose the best strategy by taking advantage of the newly revealed situations. Using a constant discount rate ignores this reality and has a bias against long-term projects and strategic decisions, which we focus on in this thesis.

2. The probability of outcomes is not clear in a complex system.

The NPV deals with risk as an adjustment factor, which is accounted for by a combination of probabilistic scenarios and change of discount rates. In the real world of uncertainty, however, the probability of each scenario will probably differ from what managers originally expected. The effectiveness of the expected NPV, which depends on this probability, is difficult to prove due to the reliability of this assumption. As we discussed at the beginning of this thesis<sup>17</sup>, one decision on a project may create unanticipated side impacts on another project in a complex transportation system. This fundamental characteristic makes this problem too hard for managers to simply use the NPV in a railway project.

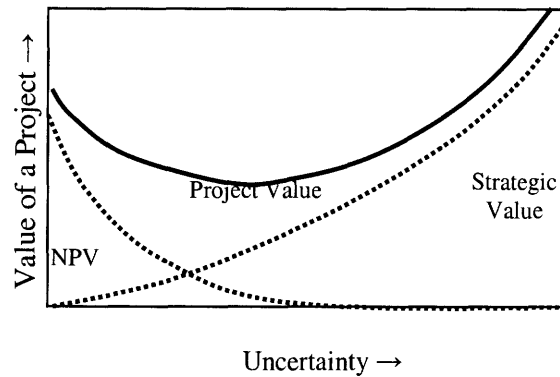
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<sup>17</sup> 1.1.2 (Motivation and Objectives)

### **2.2.3 Option Approach**

Conversely, if uncertainty is a major concern in a railway project, we can value such phased projects as will confirm whether the next phase is worthwhile. The project has strategic value on top of its cash flows when future is revealed. Consequently, flexibility also has value if it gives opportunity to cope with unexpected events. As a result, the value of these projects is actually higher than their expected NPV under uncertainty.

The key insight of this converse approach is that projects can be considered as kinds of “options,” which can increase the value of a firm when exercised with a proper timing. In this approach, uncertainty or volatility can actually increase the value of a project, contrary to the NPV approach. Previously, risk or uncertainty was a sort of barrier to a project, but using the option thinking, which can consider risk and uncertainty as positive factors, we can add value to a project. The manager can flexibly decide when and how to invest for every potential project while avoiding the negative outcomes and taking advantage of new opportunities. The value of this option will increase where the uncertainty increases. This strategic approach enables managers to utilize uncertainty instead of trying to mitigate it.



**Figure 2-6 Value of a project in different approaches under the uncertainty<sup>18</sup>**

*(Note: This figure is a conceptual model, and does not reflect a certain value of projects)*

### 2.3 Proposed Strategy

The option approach can be an effective valuation method for capital investment of a railway company, which has a large-scale and high-risk investment under uncertainty. The option approach is not a totally innovative idea; or rather, it is trying to illustrate the logic of experienced managers who have been acting to amplify good fortune while mitigating loss in investment decisions without explicitly referring to “options.” They sometimes decide to invest in a project whose NPV is zero or minus, recognizing the potential opportunities that may be realized by the investment. To understand the logic of such a decision, we have to examine what characteristics of a project can increase its value under uncertainty and provide rationale in valuing a project under uncertainty.

<sup>18</sup> This figure is originally drawn in this thesis

### 2.3.1 Flexibility

Managerial flexibility has its value under uncertainty. In dealing with uncertainty, it is effective to build flexibility into the strategy and adjust decisions according to outcomes that will occur after the initial decision. In this sense, Trigeorgis and Mason<sup>19</sup> (1987) advocated the concept “expanded NPV” in which a flexible project has an additional value to the usual expected NPV due to its ability to approach the optimum strategy:

$$\text{Expanded NPV} = \text{expected NPV} + \text{value of managerial flexibility}$$

This equation explains the significance of the concept shown in Figure 2-6. When uncertainty is not a concern, we can rely on the expected NPV. If uncertainty is critical to a project, however, the expected NPV does not reflect the strategic value of the project, and the value of the managerial flexibility becomes essential for the project.

### 2.3.2 Timing

One of the challenges of a railway project is the optimization problem in different time scales as we discussed in Chapter 1<sup>20</sup>. An option can be exercised only once, and exercising an option may eliminate other potential options. We need to think strategically to capture the long-term benefits while accommodating the short-term objectives. Therefore, we have to consider the timing of investment and its opportunity value. The opportunity value changes according to the economic condition in which a project is done.

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<sup>19</sup> Trigeorgis, L. & Mason S. P., “Valuing Managerial Flexibility”, Midland Corporate Finance Journal -Spring-, 1987

<sup>20</sup> 1.2.3 (Business Dynamics)

Managers have to meditate on the long-term design, while exercising the investment only if the condition is favorable to the project. To the contrary, if the situation is not promising, we should wait until the opportunity value improves, and finally make a decision on the investment. The value of a project varies according to the timing of the investment, and thus timing has value when we consider a project with the consequential information and opportunities.

### **2.3.3 Valuation**

The question here is how to value these strategies. If the flexibility is favorable in managing a project, how much can we invest to obtain this advantage and measure the changing value of opportunities? Real Options Value (ROV) provides the answer.

The ROV represents an application of the financial option theory to a real investment project, which has option-like characteristics. If a project has flexibility to accommodate the actual situations, the flexibility gives option-like ability to avoid bad situations while taking advantage of new opportunities. This ability leads managers to recognize the real value of flexibility under uncertainty, and thus demonstrates substantial improvements in the investment strategy. The definition of “option” is the right but not the obligation to take an action some time in the future, usually for a predetermined price and a given period. In a project, a firm has rights to invest certain amount in exchange for the intended assets at the most preferable timing just as put/call options could be exercised to buy the underlying asset at the strike price.

The application of ROV to a railway project enables managers comprehensively to consider the essential features of a railway project, which were described in Chapter 1. In addition, ROV overcomes the limitations of NPV in valuing an investment opportunity, such as the subjective probability, choice of discount rate, etc. We examine the theoretical background and practical application of ROV in Chapter 3 so as to utilize this technique for the strategic decision analysis for transportation systems.

## **Chapter 3 Real Options**

This chapter first reviews the theoretical background of real options, and discusses how a railway company can apply real options to its capital investment strategy. We also examine the valuation frameworks of real options to use it in a real project. In Chapter 2, we pointed out the critical roles of flexibility and timing in a project, and introduced the real options value (ROV) to measure their values. In Chapter 3, we go through the details of ROV, which can be an effective tool for investment strategies under uncertainty where the NPV does not work well neither as a valuation method nor decision analysis tool.

### **3.1 Theoretical Background**

#### **3.1.1 Project and Options**

In the financial market, options give the owner the right to buy (call) or sell (put) a financial asset (e.g., stock) at a predetermined price within a certain period of time, without the obligation to do so. This right provides the owners with unlimited potential gain in the future, while the lack of obligation protects them by limiting the downside risk. They can exercise options and take a gain if they can expect enough returns. If the option is not exercised, the only cost is the price of the option. This asymmetrical payoff gives values to options.

Projects often contain option-like characteristics, and we can treat investment decisions

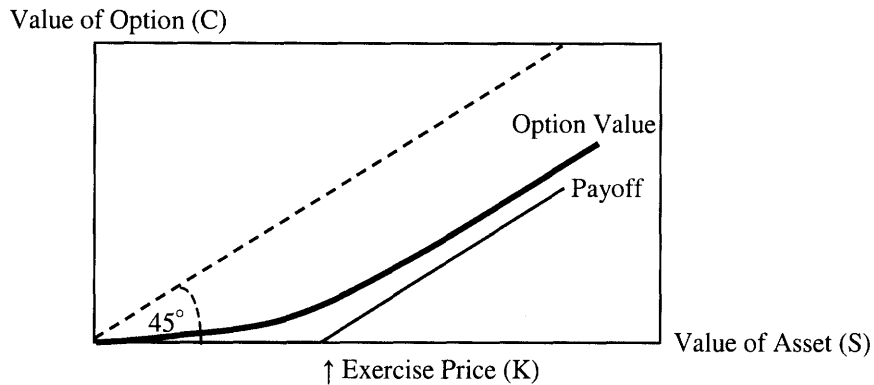


as exercising of options. Managers have options to invest in projects, but do not have to exercise their options in every situation. In addition, they may wait for more information and make decisions later. If the investment is irreversible, there is an opportunity cost of investing now rather than waiting. Moreover, they can design a project with managerial flexibility to adjust to unexpected events during the operating period. The value of these option-like characteristics will increase when the potential outcomes of a project become more uncertain.

This idea is quite similar to financial-options methodology. Managers identify options in a project, and estimate the cost (exercise price) and cash flows (underlying asset) of the project. If the situation looks promising, the manager exercises the option and invests in the project; if it does not seem feasible, the only loss is the cost to acquire the option. This is different from the traditional approaches (e.g., NPV) we reviewed in Chapter 2, and allows a more strategic approach to projects.

### **3.1.2 Value of Options**

The real options provide us with unlimited gain and limited loss for a project, and this asymmetrical payoff is the source of the value of options. Figure 3-1 shows the value of options (call-option) where “value of asset” is the expected cash flows, and “exercise price” is the initial investment in a project.



**Figure 3-1 Value of Option (Call Option)**

If the value of asset exceeds the exercise price, we can invest in the project and take positive returns (payoff =  $S - K$ ). When the value of asset is below the exercise price, however, we do not have to exercise the option, and the payoff remains zero. Therefore, the payoff of options can be the maximum of either 0 or  $S - K$ .

However, immediate payoffs may not reflect the full value of options because the option value exceeds the payoff due to its expectation in the future. A higher payoff might be obtained if we wait to invest until situations become more advantageous while the worst outcome is limited to zero. Therefore, managers always have potential opportunities to increase the returns on top of the immediate payoff. This reasoning explains why the options value is not equal to the payoff line in Figure 3-1.

Here are the parameters, which actually determine the value of options:

$S$  = asset price

$K$  = exercise price at which the asset can be bought (call) or sold (put)

$T$  = time remaining until option expires

$\beta$  = standard deviation of returns for asset (volatility)

$R$  = risk-free rate of interest

In terms of the relationship to the option value, as the greater the asset price ( $S$ ) relative to the exercise price ( $K$ ), the payoff increases, and the option value thereof increases.

Similarly, the greater the exercise price ( $K$ ) relative to the asset price ( $S$ ), the lower the option value. Also, an option with a longer term to expiration is the same as an option with a shorter term plus additional time. Therefore, the longer the term to expiration ( $T$ ), the higher the option value. Volatility of the underlying asset is critical since options have a limited (zero) downside and a unlimited (positive) upside returns, and increased volatility expands the potential range of expected returns, and increases the option value. The risk-free rate is applied to discount the future cash flow in ROV, and a higher interest rate will decrease the option value.

**Table 3-1 Relationship between the option value and each parameter**

Parameters	Asset Price ( $S$ )	Exercise Price ( $K$ )	Time to Expires ( $T$ )	Standard Deviation ( $\beta$ )	Risk-free Rate ( $R$ )
Correlation	+	-	+	+	-

### 3.1.3 No-Arbitrage Approach

We review the underlying concept in the option-pricing problem. The critical concept behind the ROV is “no-arbitrage approach” where two different assets with the same payoff must have the same price. In other words, if we replicate an asset with another portfolio that has the same payoffs (cash flows), the values of these assets are equal to each other. Therefore, we can determine the price of an asset by simply summing up the value of parts in the replicated portfolio. We will illustrate this concept with a simple example<sup>21</sup>.

Assume a firm has an opportunity to invest in an asset that requires an initial investment of \$100 now and yields uncertain payoffs one year later. The payoff is \$125 in the “up” state and is \$80 in the “down” state. The firm can invest \$100 and receive either \$125 or \$80, but the probability is unknown. In this situation, one effective strategy is to buy a call option, which gives the right to buy the asset in \$100 next year. Then, the payoff is \$25 in the up state and \$0 in the down state. Suppose another strategy is to build a portfolio with the asset (X%) and \$99 risk-free security (Y%), the price of this portfolio is  $\$100X - \$99Y^{(1)}$ . When the security becomes \$100 after a year, the up state payoff is  $\$125X - 100Y^{(2)}$  and the down state payoff is  $\$80X - \$100^{(3)}$ . If the two strategies have the same value, (2)=\$25 and (3)=\$0. Solving these equations yields  $X=5/9$ ,  $Y=4/9$ , and (1)=\$11.56.

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<sup>21</sup> Lecture on Finance Theory 2 (15.402 at MIT) by John Chalmers, November 18, 2002

**Table 3-2 Three strategies for investment in a risky asset**

	Year 0	Year 1 (Up State)	Year 1 (Down State)
Directly investing	-\$100	\$125	\$80
Using call option	-C (Price of option)	\$25 (\$125-\$100) Exercise	\$0 (\$80-\$80) Not Exercise
Partly financing by risk-free security	\$100X-\$99Y	\$125X-\$100Y	\$80X-\$100Y

The obvious result is that we can determine the price of an option by building a portfolio that replicates the payoff of the option. In addition, the option price is independent from the probability of outcomes, but depends on the possible range of outcomes (volatility). Furthermore, since there is no risk in this transaction, we can use the risk-free rate as an appropriate discount rate in valuing the cash flows.

In Chapter 2, we examined the effectiveness of NPV, and concluded with its two critical drawbacks (ambiguous discount rate, and unclear probability). This no-arbitrage approach is an essential concept in valuing options since it adjusts a situation so that the risk-free discount rate applies and there is no need to concern about the probability of outcomes.

### 3.1.4 Complete Market Assumption

The rationale to apply a replicating portfolio in the no-arbitrage approach requires an important assumption of “complete market.” This assumption indicates that capital market is sufficiently complete so that we can build a portfolio whose value is perfectly equal to that of a project. In other words, we can exchange real options for a project with financial securities as if the project could be treated as stocks. Therefore, we can apply the financial options pricing model to the ROV method.

Dixit and Pindyck (1995) developed the real options approach with this complete market assumption<sup>22</sup>. However, every real option is not traded in a market. For instance, a development right of an oil field can be traded, but an expansion right of a railway is difficult to sell or buy. Myers (2003) explained this problem and argued that assuming complete markets is enough to value real options<sup>23</sup>. Since the purpose of valuing real options is not actually to sell or buy the options but to measure the value in managing investment activities, managers can measure the value of real options as if they were traded in a market, and price them based on the no-arbitrage concept. We can understand this reasoning when we review the concept of NPV, in which we assume that non-traded assets (projects) can be valued by using the same discount rate of traded assets (securities) that have equivalent risk and returns to the projects.

This is a critical assumption in applying the ROV to transportation systems where real options are not traded. We examine this assumption to clarify the applicability of ROV

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<sup>22</sup> Dixit, A.K. & Pindyck, R.S., “The Options Approach to Capital Investment”, Harvard Business Review, 1995

to this research. We explain the theoretical correctness of this assumption by the following two steps.

1. We can price non-traded real options by the value of comparable traded securities.

This assumption is satisfied when using a pricing theory in which the value of an asset is estimated by comparing it with similar assets with known prices. For instance, we generally consider the price of a similar deal when we try to value a used car although we do not actually trade the two cars. Likewise, when managers value a potential project, they can consider a similar financial investment (security), which resembles the project in risk and returns even if they do not sell/buy the project by the securities. This approximation pricing is actually one of the most traditional and widely accepted theories in the finance field. Theoretically, the difference between traded assets and non-traded assets does not matter in pricing the value in this process.

The typical application of this theory is the CAPM<sup>24</sup> by which we adjust the discounted rate of a project based on the relationship between the project and market portfolio. The relationship is characterized by the parameter  $\beta$  (covariance). The CAPM actually prices the non-traded asset (project) based on the comparable values of traded securities in the market. The CAPM is currently applied to many theoretical discussions in valuing a project. If we use the CAPM in a real project, we can apply the same pricing theory to ROA and we can price real options by market securities.

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<sup>23</sup> Lecture on Real Options Seminar (15.975 at MIT) by S.C. Myers, February 10, 2003

The CAPM was, however, originally built to price a market asset although it is currently applied to a real project. Therefore, there is a practical problem in using the CAPM in a project. According to the CAPM, the price of an asset is determined by its  $\beta$  :

$$\beta : \text{cov (asset, market portfolio)} / \sigma^2_{\text{market portfolio}}$$

However, the  $\beta$  is difficult to determine in a project as we discussed in Chapter 1.

Luenberger (1998) proposed Correlation Pricing Theory (CPT) to practically use the concept of the CAPM in a project, and verified its theoretical accuracy and correctness in the financial literature<sup>25</sup>. The CPT has a similar form as the CAPM, but we do not have to estimate the  $\beta$  of a project. We can regard the CPT as a more convincing example of the approximation pricing theory in real options problems.

The formula of the Correlation Pricing Theory is:

$$V = 1/R \{ E(y) - \text{cov}(y, m) [E(m) - P_m \cdot R] / \sigma_m^2 \}$$

where

V: value of a non-traded asset “y”

R:  $1 + r$  (r: risk-free rate of interest)

E (y), E (m): expected payoffs of “y”, and security “m”

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<sup>24</sup> CAPM=Capital Asset Pricing Model (2.1.2)

<sup>25</sup> Luenerger, David G., “Investment Science”, Oxford University Press, 1998



$\text{Cov}(y,m)$ : covariance between the “y” and “m”

$P_m$ : current price of “m”

$\sigma_m$ : variance of “m”

In this formula, “m” is a security portfolio (not a market portfolio), which is the most closely correlated with “y”. The correctness of the CPT is shown by the fact that it gives precisely the same result as the CAPM if both were exactly calculated, so there is no-arbitrage between the CPT and CAPM. The only difference is that the market asset in CPT does not have to be the market portfolio. The form of CPT is more convenient by avoiding the  $\beta$ , and showing the theoretical process in pricing a non-traded asset with known prices of traded securities. The CPT can price a non-traded asset by adjusting the price of comparable marketed assets. Applying the CAPM and CPT in the valuation problem of a project indicates the correctness of pricing non-traded real options by market securities, which replicates the payoff of real options.

2. We can build a security portfolio, which completely replicates the payoff of real options.

This assumption is readily satisfied in any linear pricing model, such as the CAPM or CPT. The linearity of the CAPM and CPT can be shown by the fact that they use the projection of payoffs into a norm linear space, known as a Hilbert space. The random payoffs of an original set of “n” assets can be replicated as corresponding “n” vectors in a

Hilbert space where every vector ( $v$ ) can be written with the norm vectors ( $e_i$ ) and their coefficients ( $a_i$ ) as:

$$v = \sum_{i=1}^{\infty} (a_i \cdot e_i)$$

This linearity of projected payoffs is an underlying concept of the CAPM and CPT. The important result of the linearity is that the value of an asset can be stated by a number of norm securities rather than single optimal portfolio. This linearity enables us to price a collection of assets by using a combination of securities. If the non-traded asset is approximated by a linear combination of securities, the asset is assigned a price equal to that of the corresponding linear combination of securities.

The number of distinct securities is the number of risks and payoffs, so any combination of risk and payoff can be matched in countless ways. Providing completeness with respect to any conceivable state variable is not possible but, still, we can ask the common-sense question: *“Does the existence of real options allow investors to expand the range of attainable portfolio risk characteristics in any significant way? If the answer is no, we can replace real options with existing securities, so the market is complete”*<sup>26</sup>.

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<sup>26</sup> Myers, Stewart C., April 23<sup>rd</sup>, 2003

## 3.2 Application to Railway Projects

Brealey and Myers (2000) classified the common and important real options found in capital investment projects in the following manner<sup>27</sup>: expansion option, abandon option, wait option, and switch option. In this section, we examine how we can use these options based on the characteristics of a railway project, which we have discussed in Chapter 1.

### 3.2.1 Expansion Option

This option makes follow-on investments if the immediate project succeeds. Managers often invest in a project for strategic reasons. Such a project gives not only its own cash flows but also expansion options, which can take advantage of new opportunities and provide additional gain in the future.

This option is very critical for a railway company since the railway system often has an optimization problem in different time scales<sup>28</sup>. Managers are required to consider the long-term plan when they invest in a project. In another word, managers have to design a project so as to leave options to expand the system in the future. Considering the long-term plan in a project may increase its cost. However, we can obtain expansion options by paying this additional cost in the initial investment. In this case, the price of options can be the additional cost, and the underlying asset is the potential cash flows in the future projects. Using the real options approach, managers can recognize if the additional cost is worth paying in this case.

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<sup>27</sup> Brealey, Richard A. & Myers, Stewart C., "Principle of Corporate Finance", Irwin McGraw-Hill, 2000 pp.619

Moreover, a railway project has significant side effects on the land use. Investing in a project may bring another opportunity to expand the business in the future. For example, building a new station or line will encourage regional development through the new transportation service. Therefore, the population around the railway system may increase, and the incremental demand enables us to expand the railway system by investing in another project. Thus, we can acquire expansion options through the initial investment. In this case, the price of this option is the initial investment of the immediate project. Managers can reasonably value the initial investment by considering the value of expansion options in addition to the cash flows of a project.

Another example is the business model that combines the real estate with the railway system. If a railway company purchases the land around the proposed new station or line before the project, the company can expect capital gain by developing the land later. Thus, the company can reserve the extended benefits of the project within the company to recover a part of the railway project. In this case, the railway project provides expansion options to develop the real estate, and managers can invest in a railway project expecting potential profit from these options. Furthermore, the difference between the real estate and the railway in terms of the sensitivity to the market fluctuation helps managers to diversify their business activities under uncertain business circumstances.

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<sup>28</sup> 1.2.3 Business Dynamics

### **3.2.2 Abandon Option**

A project has additional values if managers can abandon it depending on to the situation during the operating period. As we need to consider the value of expansion options in case of success, we have to recognize the value of abandon options, which limit the negative impacts in case of failure.

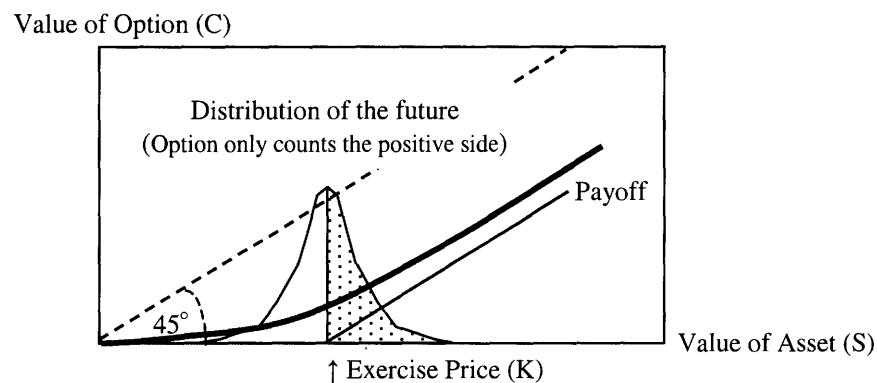
In a railway project, however, it is usually difficult to exercise this abandon option due to the social responsibility as infrastructure. In Chapter 1, we discussed institutional risks in a railway project, and argued the difficulty in using an exit strategy even if the demand is below the forecast. In addition, the railway system requires high fixed cost to realize its low operating cost, so cannot drastically reduce its total cost. These facts make it difficult to limit the downside impacts once the operations start.

This is a critical difference between a railway project and other capital investments where abandon options can be obtained with a certain cost or contracts, so as to manage the risk exposure under uncertainty. Therefore, in a railway project, managers have to make effective use of other options to manage the risks. For example, dividing a project into several phases costs more than investing in the whole project at a time. This strategy, however, gives the similar effect to abandon options since not entering into next phases can abandon the rest of the project when the initial project fails. This is actually using expansion options to recover the disadvantage of not holding abandon options in a project.

### 3.2.3 Wait Option

This option enables us to wait and learn before the investment. The value of options exceeds the immediate payoffs due to the asymmetrical distribution of the future in Figure 3-2. Using options captures the positive results while avoiding the negative outcomes. Although a project has zero or negative payoffs, it still has a certain value if we can apply the option to wait. We can exercise the option only when the situation changes and positive payoffs are available. Similarly, we do not have to invest in a project only because the project makes positive returns. If we wait on the investment, the project may have higher profit in the future than investing now.

However, projects provide cash flows just as stocks give dividends. The right not to invest now has values, but we lose the potential cash flows, which could be gained while waiting. Therefore, managers have to compare the value of wait options with the cost of holding (or buying) such options.



**Figure 3-2 Asymmetrical distribution gives values to options**

In a railway project, wait options work to determine the timing of investment. For example, station development projects create new business opportunities for a railway company. Developing a business (e.g., retail shop, restaurant) in a station can provide more convenient service to passengers, while considering them as potential customers. However, creating a business space in a station is expensive because the station was originally designed only to accommodate facilities required for operating railway systems, and changing the design has various constraints in order to maintain the current performance of systems. The business has to be highly profitable to effectively use such an expensive space. Therefore, managers have to analyze the market situation with wait options, and invest in projects only if they can expect enough profit from the business. In general, station development is advantageous to railway companies because most stations are their own properties where competitors usually cannot enter. This wait option allows managers to determine the proper timing and maximize such advantages in investment.

Another example is a modernization project. Managers try to enhance the performance of systems or reduce the maintenance cost by replacing the existing facility with an advanced one. It is critical for a railway company to introduce new technologies to increase its competitive advantage in the market. However, new technology always has uncertainty as we discussed technology risks in Chapter 1. This wait option allows managers to wait and see the effectiveness of the new technology, while holding the right to use the technology and modernize their system. This wait option gives a certain benchmark to managers who are facing the investment-timing problem in a project.

### **3.2.4 Switch Option**

The switch option provides the ability to vary the output or production methods according to the situation. If a firm can flexibly vary its products by exercising this switch option, the firm can be less vulnerable to the market fluctuation due to its adaptability to the market trends. Similarly, a firm with dual production methods is more valuable than with a single method due to its ability to stabilize operating costs. This built-in flexibility has substantial values under uncertainty where the market demand or resource cost is frequently changing. However, the flexible design makes the system complex and expensive. Managers have to value the switch option in making a decision on whether the flexibility is worth investing in.

In a railway project, there exist high market risks and the fixed system of railways prevents managers from easily adapting their system to the market. Therefore, this option is critical in designing a railway system. The railway has the efficiency in its operation in exchange for the fixed cost and location of facilities. Therefore, building flexibility in a railway system is effective in taking the benefit while avoiding the negative side of its characteristics.

For example, the switch option is useful in designing a railway network. Managers often face difficulty in deciding if they should build additional tracks or points in their network. Although it costs, having such extra facilities gives flexibility to the network, which allows the railway company to operate additional trains in a peak period or take alternative routes in case of accidents.



Another example is the design of rolling stock. If we design rolling stock so as to drive both on high-speed and conventional rails (e.g., dual gauge car), we can flexibly operate such rolling stock to accommodate the fluctuation in trip demands. Moreover, passenger rail, especially high-speed rail, has different customer segments such as business trip and family travel. Flexible design can easily capture the preferences of different types of customers by switching the interior design while using the same car. Recognizing switch options in these examples gives practical benchmarks in making an investment decision.

### **3.3 Valuation Framework**

We reviewed the theoretical background of the real options value (ROV), and how we can make practical investment decisions by applying the ROV to a railway project. We now examine the valuation framework of ROV. The attractiveness of ROV is its independence from a choice of discount rates and subjective probabilities. A portfolio of securities that replicates the cash flows of a project quantifies the value of a project as well as the optimal timing of investment to maximize the value. The ROV is an application of the financial options theory, and there are two major valuation frameworks to value financial options: Black-Scholes Formula and Binominal Model. We compare the two methods and build a valuation framework to answer the ROV problems in a railway project.

### 3.3.1 Black-Scholes Formula

Black and Scholes developed a pricing method of options as the following compact formula. Although the formula mainly deals with only European calls<sup>29</sup> (without dividends), it has been refined since then and widely used in the financial market.

The Black-Scholes Formula is:

$$\begin{aligned}C_0 &= S_0 \cdot N(d_1) - X \cdot e^{-rT} \cdot N(d_2) \\d_1 &= [\ln(S_0/X) + (r + \sigma^2/2) T] / (\sigma \cdot T^{1/2}) \\d_2 &= d_1 - (\sigma \cdot T^{1/2})\end{aligned}$$

where

$C_0$ : current option value

$S_0$ : current stock price

$N(d)$ : probability which will be less than “d” in a normal distribution

x: exercise price

e: base of the natural log. (=2.71828)

r: risk-free interest rate

T: time to maturity of the option in years

ln: natural log function

$\sigma$  : standard deviation of annualized continuously compounded rate of return on the stock.

This formula is similar to  $C = f$  (asset price) –  $g$  (loan). This formula represents the concept in which an option has value equal to the replicating portfolio (buying a stock by borrowing) where the standard deviation gives a measure to the possible range of payoffs.

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<sup>29</sup> European options can be exercised only at the expiration while American can be exercised anytime before the expiration.

This valuation method is based on the statistical movement of stocks, and the movement is assumed to be random around the trend line.

The practical problem of the Black-Scholes Formula is, however, the focus on European options model where we can exercise options only at the expiration. As we described, a variety of options can be applied in a railway project, and many of them should be exercised whenever the situation is optimal for the investment, even prior to the expiration. the Black-Scholes is a compact and effective tool to price an option, but we need to apply another model in pricing options in a railway project.

### **3.3.2 Binominal Model**

The Binominal Model assumes many periods in exercising an option. This model varies the value of underlying assets based on the volatility in a given period, and rolls back the values from the expiration. For each period, the model compares the value of immediate payoff and holding of the option, and decides whether the owner should exercise the option. Thus, this model determines the optimal strategy of exercising options, and the value of options at the time of investment by summing up the values throughout the whole period.

Value of holding the call option for the next period is:

$$C_h = [p \cdot c_u + (1-p) \cdot c_d] / (1+r)$$

where

p: risk-neutral probability

$c_u$ : value of option at end if up

$c_d$ : value of option at end if down

The risk-neutral probability is a key idea for connecting sequential periods under uncertainty. We can calculate this probability by applying the no-arbitrage concept. According to this concept, we can replicate the payoffs of an option as if we bought an asset by borrowing a risk-free loan.

Assuming the asset share is X, and loan share is Y, the replicated payoffs are:

$$X \cdot S_u + Y \cdot S(1+r) = C_u$$

$$X \cdot S_d + Y \cdot S(1+r) = C_d$$

where

u: parameter to determine the S at end if up ( $e \cdot \exp(\sigma \sqrt{\Delta t})$ )

d: parameter to determine the S at end if down ( $e \cdot \exp(-\sigma \sqrt{\Delta t})$ )

r: risk-free interest rate

When we solve the equations, the option price (= value of the portfolio) is:

$$C_h = [(1+r-d)C_u + (u-(1+r))/C_d](1+r)/(u-d)$$

We can rewrite the above formula by using a factor “q”

$$C_h = [q \cdot C_u + (1-q) C_d]/(1+r)$$

$$q = (1+r-d)/(u-d)$$

This process leads us to adjust the investment situation as if we could calculate the expected value of options with binominal probabilities  $q$  and  $(1-q)$ , which are risk-neutral probabilities.

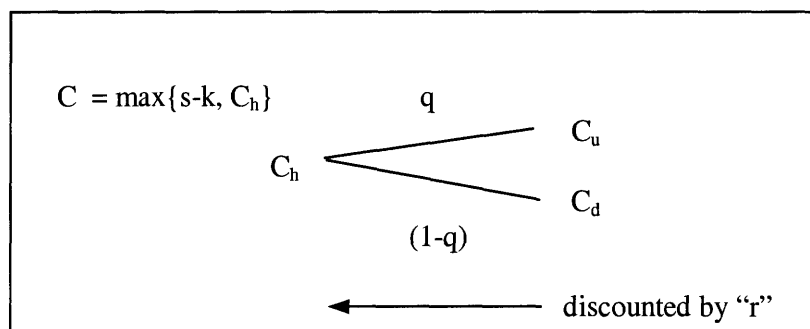
Finally, the value of options is the maximum of their immediate exercise, holding for another period, or zero:

$$C = \max\{s-k, [p \cdot c_u + (1-p) \cdot c_d]/(1+r), 0\}$$

where

$s$ : value of asset

$k$ : exercise price



**Figure 3-3 Expected value of option**

The above figure is similar to a decision tree, and we can go backward from the last to first period to value C. In additions, we can use risk-neutral probabilities instead of the assumed probability, and apply risk-free interest rates as discount rates.

The Binominal Model approximates the movement of the value of underlying assets as a sequential increase and decrease. This model actually applies the concept of a replicating portfolio over many periods, and provides a flexible and transparent method to option valuation in a railway projects.

It is hard to argue that one or another is a better decision analysis method, and we need to apply an appropriate valuation method based on the characteristics of a project, the availability of data, and the purpose of analysis. In this sense, we proposed the effectiveness of ROV in capital investment projects of a railway company, and explained the excellence of the Binominal Model in pricing the options. In the next chapter, we will analyze a real case to illustrate how we can make a strategic decision in investment problems by using the ROV.

## **Chapter 4 Case Study -Station Development-**

This chapter analyzes station development projects as a case study. As we classified railway projects in Chapter 1, a station development project is located at the “high-risk” and “mid-scale” segment in the project portfolio<sup>30</sup>. Developing several stations, specifically in downtown areas, can be a large-scale investment program, and requires managers to make strategic decisions. We proposed an example of real options to a station development project in Chapter 3. This project is an interesting case as an application of strategic decisions analysis, which we have developed in this research.

In addition, this project plays an important role in developing transportation systems. Stations are key facilities for the railway system, and effective use of stations is critical for a railway company to properly operate the system and provide better service to customers. Stations also have potential for retail business because of their advantage in locations where many passengers gather. Furthermore, stations are essential facilities in urban planning. Combining a station development with an urban renewal project may be an effective investment to achieve a revival of a downtown and real estate development. These aspects of a station make the project attractive, but various barriers (e.g., high development cost, design constraints) lead managers to difficult investment decisions.

This case describes a strategic decision, which a Japanese railway company is now facing. The company considers investing in station development projects in the Tokyo

metropolitan area, and trying to value them with the NPV analysis. Managers acknowledge the strategic importance of the projects, but also have difficulty in explaining their reasoning with the NPV analysis. We examine how real options provide a rational answer for this problem.

## **4.1 Case Description**

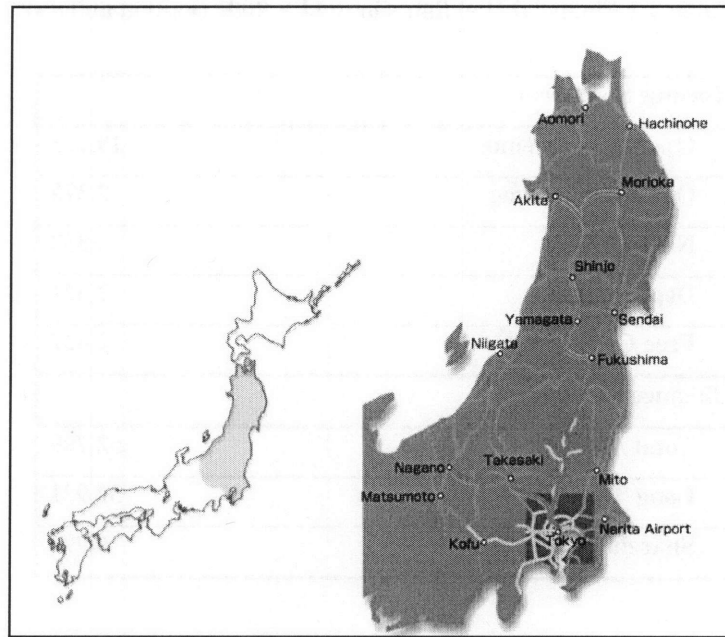
### **4.1.1 Company Information**

In accordance with the provision of the Law for Japanese National Railways Restructuring, the Japanese National Railways (JNR) was privatized into six passenger companies and one freight company on April 1, 1987. The East Japan Railway Company (JR East) is the largest passenger railway company in Japan and serves the Tokyo metropolitan area and the eastern part of the main island of Japan. JR East operates 70 railway lines (including three high speed lines), 1709 stations, and serves more than 16 million passengers daily.

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<sup>30</sup> Figure 1-3





**Figure 4-1 Operating Area of JR East<sup>31</sup>**

Table 4-1 shows the financial highlights of JR East. The company inherited a part of the large debt of JNR in exchange for the operating assets when it was privatized. This debt was so huge that repaying the interest (around \$1,600M annually) is one of the major financial burdens. Therefore, it is critical for the company to reduce the debt by effectively controlling its investment activities. However, as we discussed in Chapter 1, capital investment is a source of cash flows in the future, and indispensable to compete in the market. Therefore, managers are required to make a strategic decision on their investment activities based on a solid understanding of the business dynamics of their projects.

**Table 4-1 Financial Highlights in the FY 2001 (million dollars)<sup>32</sup>**

<b>Income Statement</b>	
<b>Operating revenue</b>	<b>19,123</b>
<b>Operating income</b>	<b>2,378</b>
<b>Net income</b>	<b>358</b>
<b>Depreciation</b>	<b>2,421</b>
<b>Free Cash Flow<sup>33</sup></b>	<b>2,627</b>
<b>Balance Sheet</b>	
<b>Total Asset</b>	<b>52,799</b>
<b>Long-Term Debt</b>	<b>32,931</b>
<b>Shareholder's equity</b>	<b>6,998</b>

The company is involved not only in railway operations, but also in other business such as retail sales, shopping centers, hotels, real estate development, etc. These businesses have synergistic effects with the railway business, and help the company to diversify its portfolio.

JR East recently announced a medium-term business plan, whose completion is targeted for the fiscal year of 2006. One of the main strategies to achieve the plan is “station development”, which enhances the business activities at stations by optimizing the allocating of facilities both from the railways and other businesses’ points of view. Although the Japanese economy is still uncertain, and not fully recovered from the recession in the late 1990’s, the company is finding opportunities in the currently evolving deregulations and restructuring of industries, and decided to begin with three projects in 2003.

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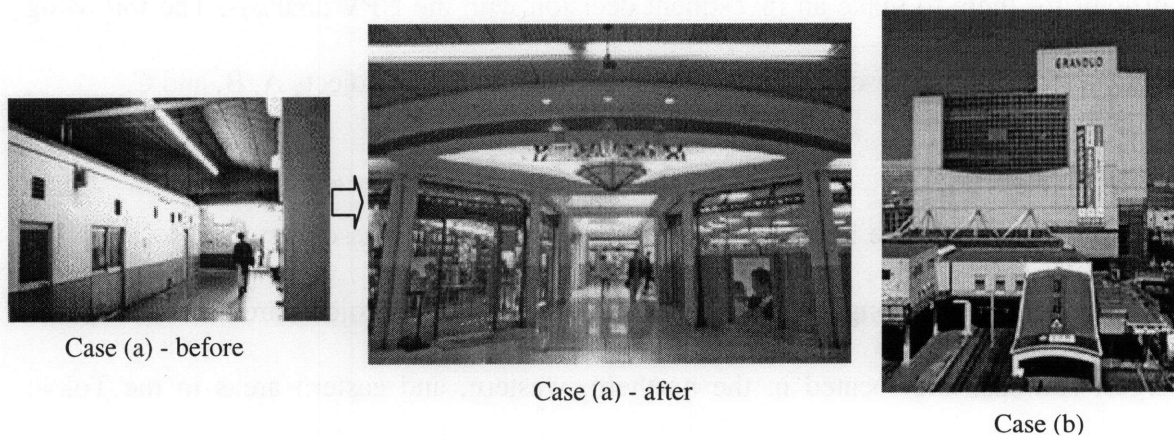
<sup>31</sup> Corporate Guide of JR-East in 2001

<sup>32</sup> Annual Report in 2001, JR East

### 4.1.2 Station Development Projects

These projects change stations to accommodate both railway and business activities. Previously, most stations allocated their space only for railway facilities. However, the railway system has a long history, and advances in technology and management now enable the system to operate with smaller space and less people. Therefore, there is an opportunity to review the layout of stations and create business space, which can generate cash flows in addition to the railway business. Moreover, reviewing the layouts and adjusting them to the current operations make the system more efficient. These projects are effective to enhance the performance both of the railway and related businesses.

Figure 4-2 is an example of the projects. One approach is to renew the interior of the station, remove the unnecessary facilities, and create a shopping mall <sup>(a)</sup>. Another approach is to construct a building over the station <sup>(b)</sup>, which is an effective way of developing real estate in a limited area such as downtown. These projects actually change the station from a space to pass through into a place to gather.



**Figure 4-2 Examples of the station development**

<sup>33</sup> Cash flows from operating activities and cash flows from investing activities.

JR East has already developed some suburban stations by taking one of those methods, but the new series of projects, which JR East is now planning, more drastically change a station by combining various approaches and making large-scale investment in its hub stations in downtowns. These projects are very important to achieve the medium-term business plan of JR East, but also quite uncertain due to their complexity and lack of precedents. Managers are required to make a strategic decision so as to mitigate the risk and capture the benefits while moving fast and creating future opportunities under uncertainty.

At this time, JR East is considering the development of those stations, which have more than 200,000 daily passengers in the Tokyo metropolitan area. There are around 30 stations, which meet this requirement, and managers narrowed the potential projects down to three as the initial investment in this strategy. Managers recognize the importance of this investment, which opens up the potential of this strategy. However, the uncertain business environment, and relatively expensive construction costs make it difficult for them to make an investment decision with the NPV analysis. The following figures and tables represent the information for the proposed projects A, B, and C.

Figure 4-3 indicates the ranking (in terms of the number of passengers) and locations of the three projects. Among the targeted stations, the proposed projects are the 8<sup>th</sup>, 17<sup>th</sup>, 27<sup>th</sup> largest stations, and located in the northern, western, and eastern areas in the Tokyo metropolitan area. Providing the top five stations are so large and complex that each project can be very specialized, projects A, B, and C are good representatives of the

potential projects in terms of their scale and location in this company. Therefore, it is very critical for managers to succeed in the three projects, and move on to the potential projects by applying similar plans, whose effectiveness can be verified by the initial success.

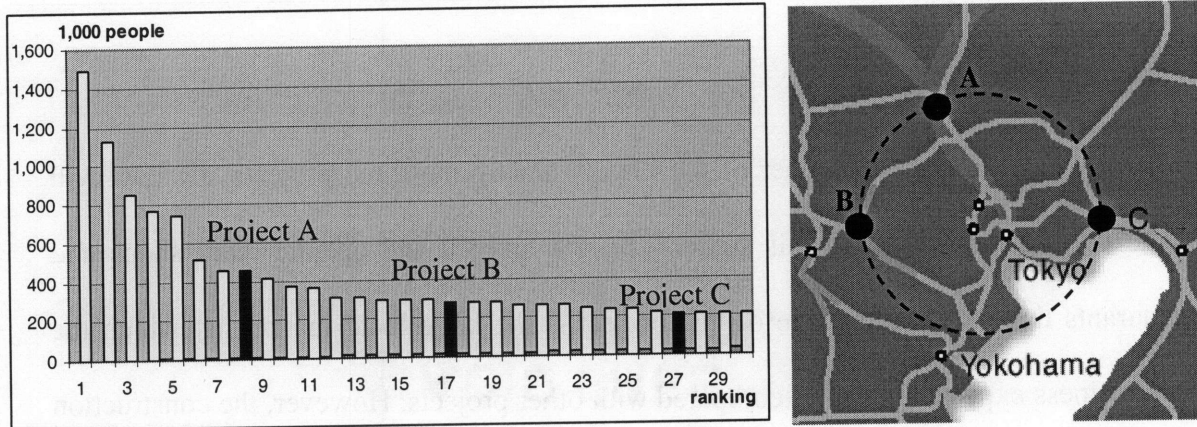


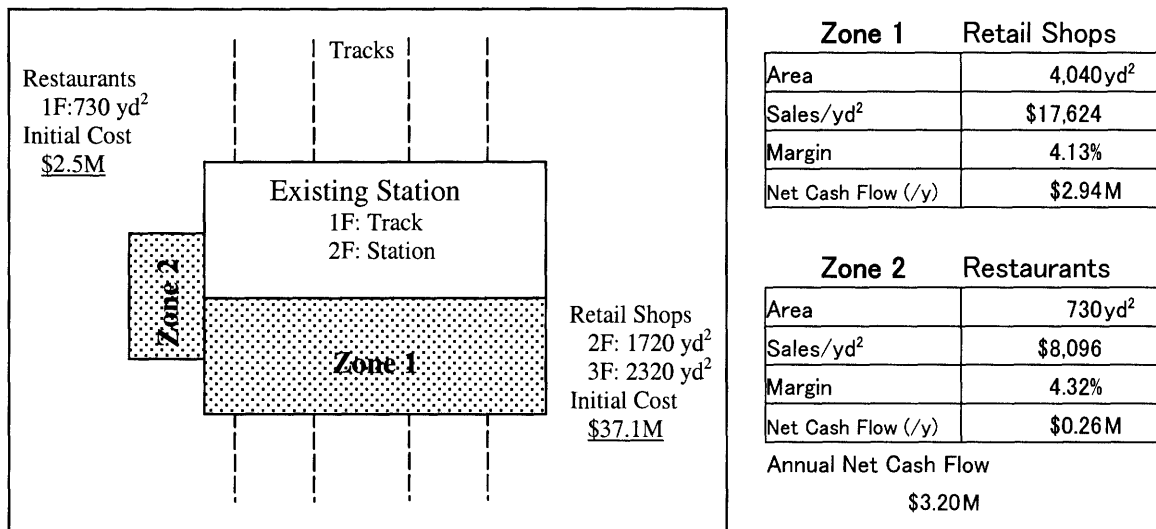
Figure 4-3 Ranking and location of projects A, B, C

Table 4-2 summarizes the data for projects A, B, and C. The common strategy is to create a business space in a station by reviewing its layout and constructing buildings over or adjacent to a station. However, the accessibility to the site (= station) significantly impacts on the cost and period of the construction work, and the local market influences the expected income of the new business. We explain the details of the three projects in the following plans.

**Table 4-2 Project Data**

	Project A	Project B	Project C
Development Area (yd <sup>2</sup> )	4,770	8,556	2,050
Business Type	Retail shops Restaurants	Retail Shops Hotel	Retail Shops Café & Restaurants
Construction Cost (\$M)	39.6	40.7	11.4
Construction Period (years)	3.0	2.5	1.0
Expected Net Cash Flow (\$M/year)	3.2	3.2	1.4

Project A has the largest number of passengers among the three projects. JR East will create two business areas in this station (Zone 1 and 2), and operate retail shops and restaurants there. The advantage of this project is the large local market, by which the new business expects high sales compared with other projects. However, the construction work has to be done over many busy tracks, and will be very expensive.



**Figure 4-4 Construction and Business Plan<sup>34</sup> of Project A**

Project B is located at the center of the eastern area of Tokyo, and one of the major stations for changing commuter trains. JR East will operate retail shops in zone 1, and a hotel in the zone 2. The hotel space is very limited, and its construction work has to be done by using the zone 1 area. Therefore, the construction of the two zones has to be tied together and difficult to separate. JR East now operates small-scales hotels, which benefit from high operating rates and margins due to their specialized service for business customers, and considers a similar hotel in zone 2.

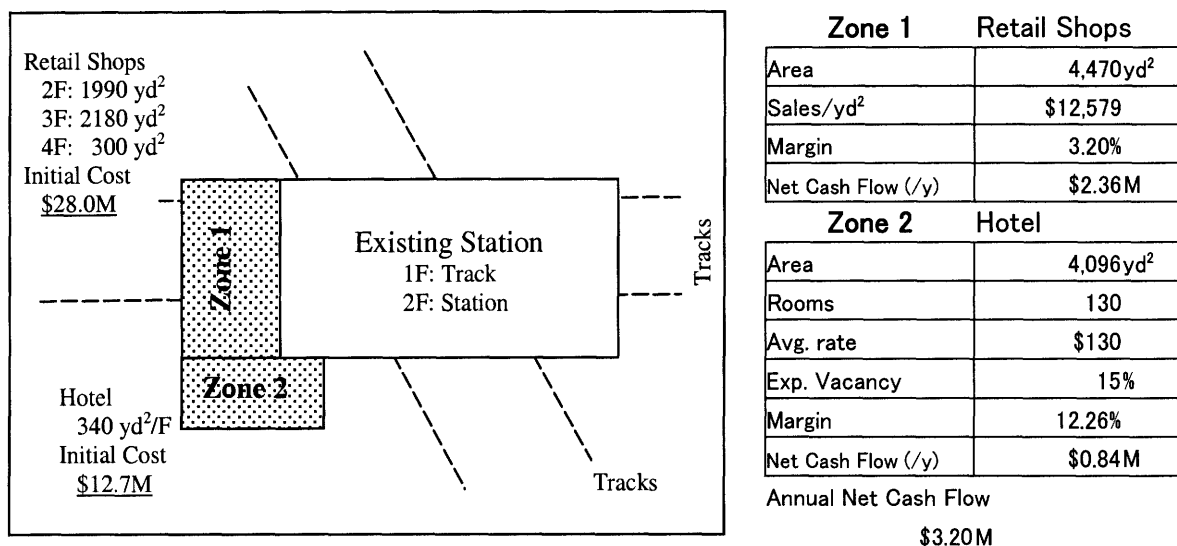
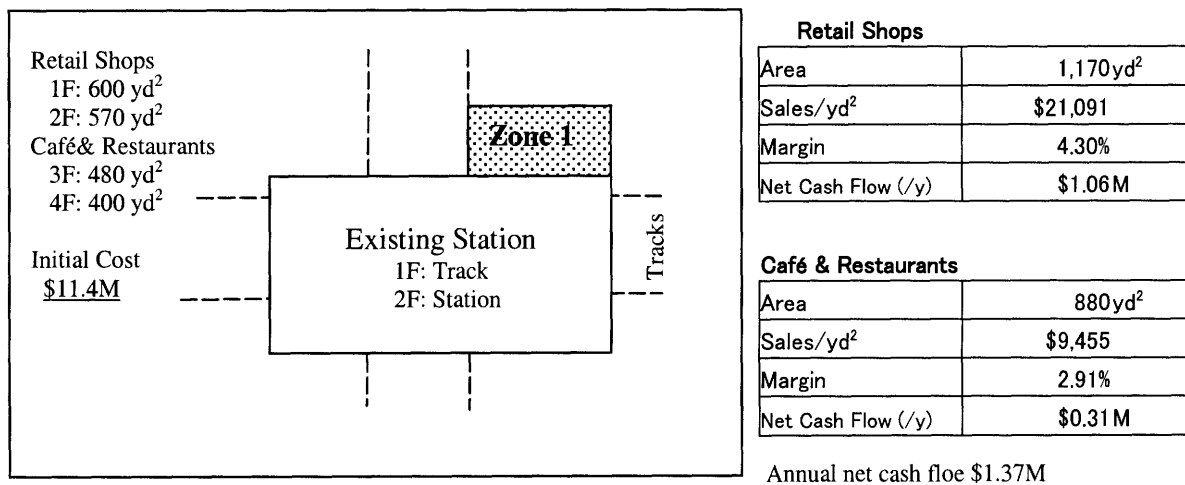


Figure 4-5 Construction and Business Plan of Project B

<sup>34</sup> The forecast of sales, margin, and net cash flow are based on market surveys of a similar business in the local market

Project C is the smallest project. It is, however, located in an area, which has many offices and community facilities around the station. Marketing surveys indicate that the number of customers is not so large, but the purchasing power per person is very strong in this area. Furthermore, its construction constraints are not so severe as the other two projects, and JR East can save construction costs in this project.



**Figure 4-6 Construction and Business Plan of Project C**

### 4.1.3 NPV analysis

In JR East, managers used to consider the payback period of a project to make an investment decision. However, they have recently decided to use the NPV as the primary benchmark for valuing an investment in accordance with the new accounting system, which regards the cash flow as an important criterion for a corporate and investment activities. Managers, however, still have difficulty in using the NPV for station



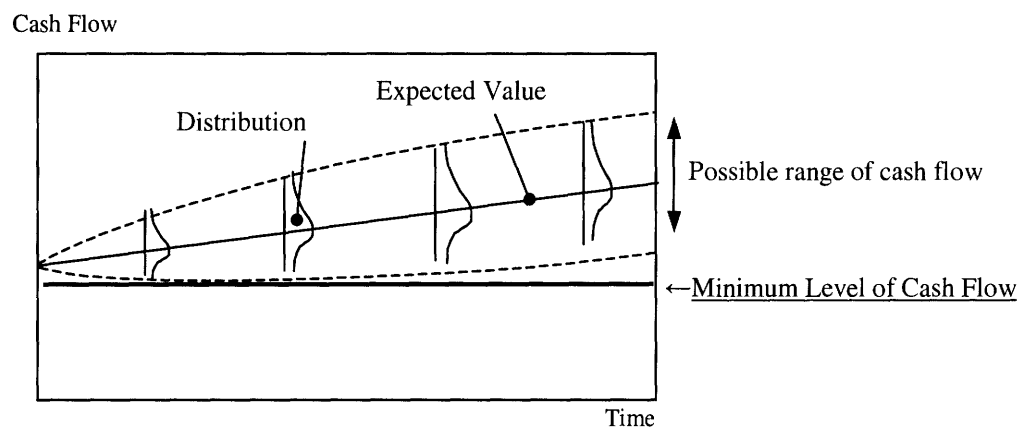
development projects. In addition to the drawbacks of NPV, which we pointed out in Chapter 1, the company has the following practical problems in using the NPV:

1. Applying the weighted average cost of capital (WACC) to determine a discount rate is difficult because the railway business is still dominant in the corporate portfolio of JR East. Managers have much experience in the railway business, and it is more stable than a new business. Therefore, using the WACC, which reflects the average risk of a firm, underestimates the risk in a new business. Also, determining the risk-premium to adjust the WACC is challenging due to the lack of historical data and complexity for the project. In addition, JR East is now trying to reduce long-term debt, and the capital structure will drastically change during the project period. These facts result in the difficulty in using the cost of capital to determine the discount rate in the proposed project, and force managers to take another approach.
2. Forecasting the cash flows over a long period is difficult because the new business is quite sensitive to market conditions, and the forecast error usually expands during the project period. Managers can forecast the cash flows for a few years based on the market survey and their experience in other projects. However, the long-term forecast is too ambiguous to use in valuing the project.

In brief, managers can properly estimate neither the expected cash flows nor the risk premium rate of a station development project under the present circumstances. To solve these problems, therefore, they decided to conservatively estimate the cash flows and use

the risk-free rate in calculating the NPV. In other words, they consider the project-specific risk not in the discount rate but in the forecast of cash flows. In practice, managers are using the following policy to value station development projects with the NPV analysis:

1. Reduce the expected cash flows to the minimum level. In other words, estimate conservative cash flows that managers can expect to be achieved even if the situation turns out in failure. Moreover, managers do not expect the growth of the cash flow; or rather, they assume the minimum level will continue during the whole project period.

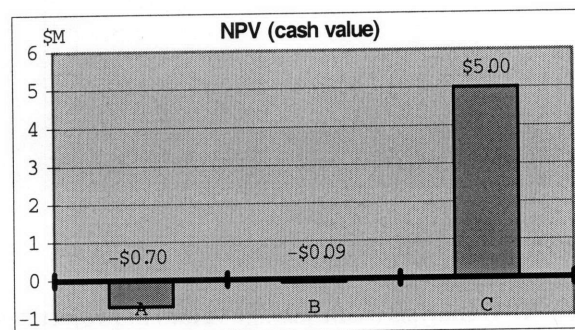


**Figure 4-7 Minimum Level of Cash Flow**

2. Use 3% discount rate, which is the interest rate on the long-term debt (20 year bond) for JR East. Repaying the debt is always a risk-free alternative of the investment, and reducing the cash flows to the minimum level and discounting it by a risk-free rate has a similar effect to using a risk-premium rate to discount the expected value of cash flows.

3. Assume 15 years as the project life in case of a business within a station (zone 1), and 20 years when adjacent to the station (zone 2). The reason for this difference is the possibility of reviewing the layout of a business space due to the additional requirement of the railway operations in the future. Therefore, business in zone 1 has slightly shorter project life than that in zone 2.
4. Do not consider the salvage value of a project. These assets are closely related to the railway operations, and are not easily converted into cash in a market. Therefore, managers only consider the cash flows of a project to avoid overestimation.

Using these steps, managers calculated the NPV for each project as seen in the following figure<sup>35</sup>.



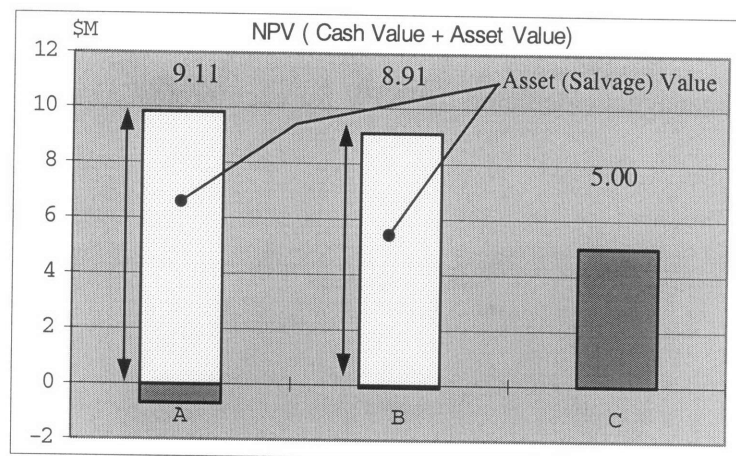
**Figure 4-8 NPV of Project A, B, C (without salvage value)**

The obvious result of the NPV analysis is that only project C makes sense in terms of the financial returns on investment. Managers, however, intuitively recognize the potential of

<sup>35</sup> For details, please see the spreadsheets at the end of this section

these projects, and need to explore the opportunities to achieve their medium-term business plan by 2006. Therefore, managers discussed the NPV analysis, and tried to increase the value of projects by quantifying their intuitive expectation. They finally concluded by adding salvage values of projects although the investment policy of JR East does not usually consider the salvage value of a similar project.

Managers estimated the salvage value based on the discounted book value (after depreciation) of the business assets in projects A and B. Figure 4-9 shows the result of this new analysis.



**Figure 4-9 New NPV analysis (with salvage values in project A and B)**

As the result, the NPVs of project A and B turned out to be positive, and managers could provide the rationale for investing in the three projects. The following spreadsheets show the calculation of the NPVs in this analysis.

**Table 4-3 Spreadsheets for the NPVs of project A, B, C (\$M)**

**PROJECT A**

**Zone 1**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Cash Flow				2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94	2.94
Asset	-5.30	-10.60	-21.20															13.88
PV	-5.30	-10.29	-19.98	2.69	2.61	2.54	2.46	2.39	2.32	2.25	2.19	2.12	2.06	2.00	1.94	1.89	1.83	10.18
NPV	6.91			Cash Value -2.00					Salvage Value 8.91									

**Zone 2**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cash Flow			0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Asset		-2.50																				
PV	0.00	-2.43	0.24	0.23	0.23	0.22	0.21	0.21	0.20	0.20	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15	0.15	0.14	1.02
NPV	2.21			Cash Value 1.30					Salvage Value 0.91													

**TOTAL**

NPV	9.11	Cash Value	-0.70	Salvage Value	9.82
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**PROJECT B**

**Zone 1**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Cash Flow			2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36	2.36
Asset	-9.33	-18.67															11.26
PV	-9.33	-18.12	2.22	2.16	2.10	2.04	1.98	1.92	1.86	1.81	1.76	1.70	1.66	1.61	1.56	1.51	8.49
NPV	7.45			Cash Value 0.18					Salvage Value 7.27								

**Zone 2**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Cash Flow			0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Asset		-12.70																				3.29
PV		-12.33	0.79	0.76	0.74	0.72	0.70	0.68	0.66	0.64	0.62	0.60	0.59	0.57	0.55	0.54	0.52	0.51	0.49	0.48	0.46	2.22
NPV	1.55			Cash Value -0.27					Salvage Value 1.82													

**TOTAL**

NPV	8.99	Cash Value	-0.09	Salvage Value	9.09
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**PROJECT C**

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Cash Flow		1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
Asset	-11.40															
PV	-11.40	1.33	1.29	1.26	1.22	1.19	1.15	1.12	1.08	1.05	1.02	0.99	0.96	0.94	0.91	0.88

NPV	5.00
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Note 1: The “Cash Flow” indicates the net cash flows from the business operations, and “Asset” means the cash flows from initial investments and salvage assets.

Note 2: The initial investment disperses during the construction periods.

Note 3: Zone 1 has 15-years operation, while zone 2 has 20-year.

## **4.2 Real Options Analysis**

### **4.2.1 Results of the NPV analysis**

The obvious result of the NPV analyses is that all projects have positive NPVs, but only project C makes sense if managers do not count the salvage value and simply consider the cash flows in valuing a project. Projects A and B are difficult to invest in when managers focus on the cash values of a project as JR East usually does.

However, managers are going to launch all three projects based on the decision supported by the NPV analysis, which will consider the salvage value of a project as an exception to their valuing procedures. The reason managers value the salvage value is that they find differences between their intuition and the NPV results, and modified the analysis so as to justify their decisions. This happens because NPV does not reflect the strategic value of a project, and cannot be a practical tool in making a decision on strategic projects, specifically under uncertainty. Subjective use of NPV, however, makes the analysis meaningless due to the lack of the logical consistency, may lead managers to wrong decisions, and result in loss of their competitive advantage in the market.

The following two points are concerns about the NPV analysis, which JR East is currently applying to the projects.

1. Project A and B value their salvage assets although JR East does not usually consider the salvage value of a similar project. The salvage value is actually a part of the NPV

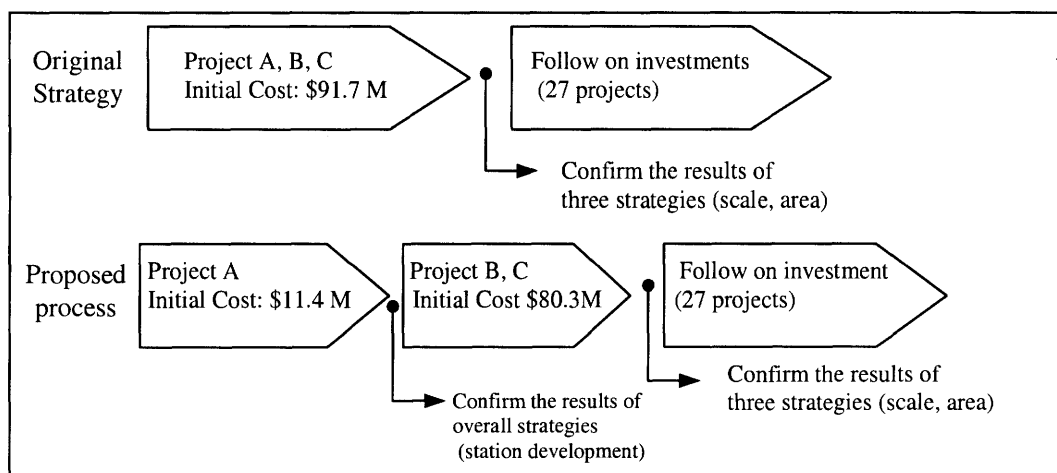
according to finance theory, but the risk aversion policy of JR East usually forces managers to focus on the cash value to avoid overestimating a project. One of the reasons is that the expensive construction cost of a station project increases the book value of assets, so the market value tends to be less than its book value. Also, some assets are related to the railway operations, and difficult to sell. Therefore, managers cannot always expect the same cash flows as the book value of an asset. Whether a firm considers a salvage value, of course, depends on the investment policy and the type of projects. However, projects A and B are exceptions to the valuation policy in JR East, and managers have to justify their reasoning for making exceptions.

2. NPV does not reflect the strategic value of the projects. The reason that managers counted the salvage value might be their expectation of the project beyond the cash flows. Since there are many proposed projects, it is reasonable that the company can benefit from future projects if the initial projects succeed. Managers, however, need to explain their reasoning by using an appropriate and consistent tool and to value their expectations.

At this time, managers have difficulty in explaining the rationale for their investment decisions although they intuitively think they should invest in all three projects. The problem is the limitation of NPV analysis in valuing these projects under uncertainty. As we discussed in this research, real options value (ROV) is an effective tool to make a decision for these strategic projects.

## 4.2.2 Valuation Process

The first step of ROV is to recognize options in the project. According to the classification of options<sup>36</sup>, wait (timing) options can be practically applied in station development projects. Managers do not have to invest in all the uncertain projects at the same time; or rather, they can invest in one of the projects, examine the results, and make decisions on other investments later. The initial project has values as a pilot project, which verifies the effectiveness of the general strategy for these kinds of projects. In this case, project C is appropriate as the first project since it has the positive cash NPV (\$5.0M without the salvage value), and requires the smallest amount of investment and the shortest construction period. Project C creates options to wait and see the results of the new strategy (station development). Managers can decide whether and when they exercise options and invest in projects A and B based on the results of the project C. Figure 4-10 illustrates the difference of the two processes, and options in the investment strategies.



**Figure 4-10 Implement Strategy**

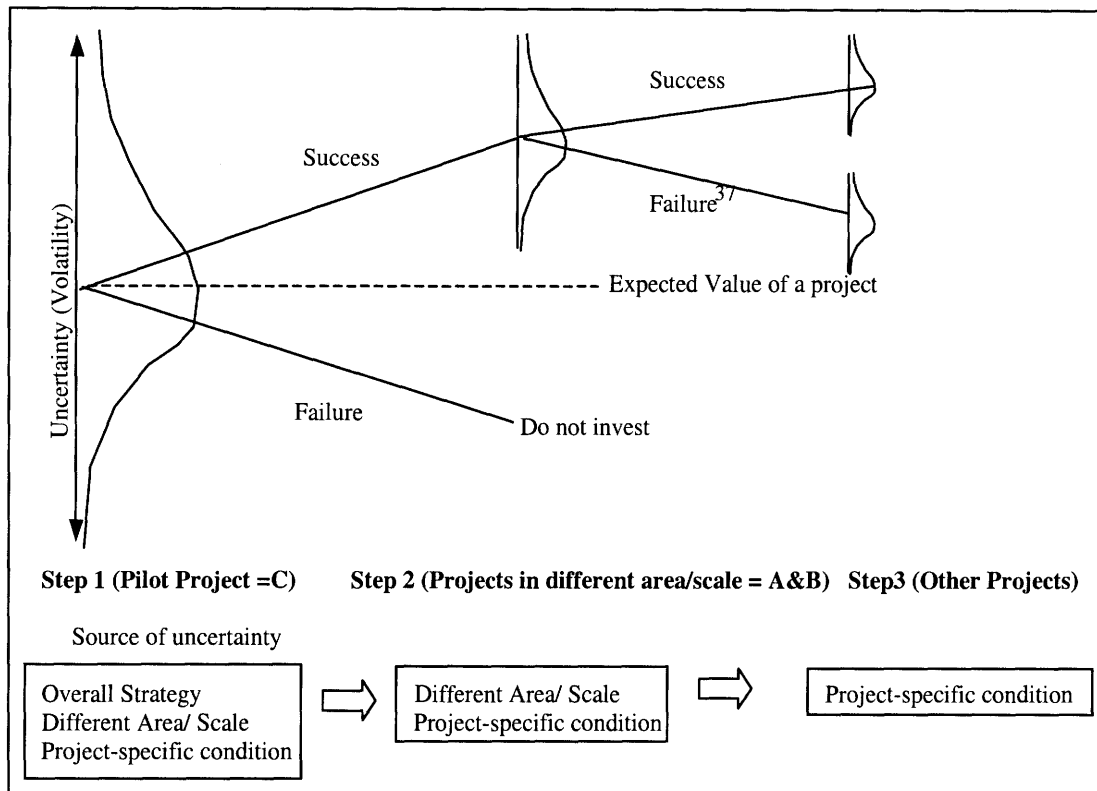
<sup>36</sup> 3.2 Application to Railway Projects



At this time, JR East has the details (e.g., construction and business plan) for projects A, B, and C. However, there is uncertainty in these projects because they do not have precedents, which help managers to forecast the cash flows. Therefore, managers can invest in project C, examine the actual cash flows, and confirm the effectiveness of their strategy. This investment will reveal the potential of station development projects, and resolves the uncertainty related to the effectiveness of overall strategy. Managers can adjust the NPVs of projects A and B based on the result of Project C.

Although the success of initial project (=C) does not necessarily indicate the success of the next projects (=A and B), managers can improve the accuracy of their analysis, and consequently make a better decision due to this additional information. If the project C succeeds, the underlying asset of their options (= expected cash flows) will increase, and projects A and B will more likely succeed. Managers can expect higher NPV and make investment in projects A and B, which also resolve the uncertainty related to the scale and area of projects.

Project-specific uncertainty remains to be unsolved even in this phase, and the uncertainty may be high in a large and complex project. Managers, however, can focus on the project-specific uncertainty to analyze the 27 projects, and their decision will be more accurate because other uncertainty is already resolved.



**Figure 4-11 Uncertainty will decrease as the investment proceeds**

The next step is to determine the parameters, which price the options. We have already obtained several parameters from the project information:

$S$  (asset price) = Present value of cash flows

$K$  (exercise price) = Construction cost

Assuming the project period is 15 years and we use the Binominal Model, which we explained in Chapter 3, one year is reasonable to avoid the complexity while keeping the

<sup>37</sup> We can not make decisions on other projects at this time because we do not have project information (e.g., construction and business plan)

model precise. In this case, managers can make investment decisions every year based on the performance of project C.

$$T \text{ (time interval)} = 1 \text{ year}$$

The interest rate of a Treasury bond is usually applied as a risk-free rate, and the average rate of the Japanese Treasury bond (10 year) in the past five years (1998-2002) is 1.5 %<sup>38</sup>.

$$R \text{ (risk-free rate of interest)} = 1.5\%$$

We use the movement of sales per unit area in the commercial industry so as to measure the volatility of the underlying assets in the projects. The underlying asset is the cash flows, which come from given areas in these projects. Since these projects have physical constraints and cannot increase the business area, sales per unit area determine the cash flows in projects. Actually, the margin rates slightly vary according to the sales, but the data neither for the net income per unit area nor the margin rates are available at this time. Therefore, we pragmatically use the fluctuation of the sales per unit area in the commercial industry to measure the volatility in this ROV analysis. Figure 4-12 shows the flow of this process.

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<sup>38</sup> <http://www.mof.go.jp/jgb.htm>

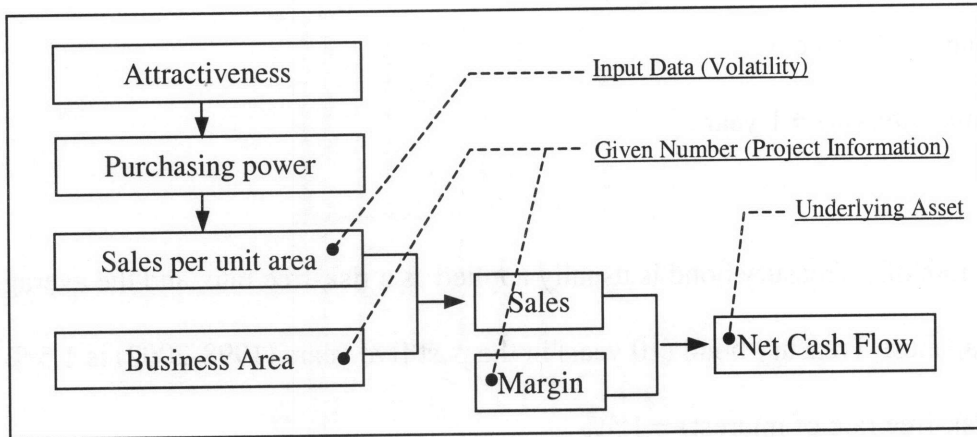


Figure 4-12 Volatility of the underlying asset

The sales per unit reflect the attractiveness of the new business through the purchasing power of customers (passengers). Since the business area is limited by the project plans, the unit sales determine the total sales of the business, and consequently determine the cash flows (underlying asset) from the project by using the given parameters.

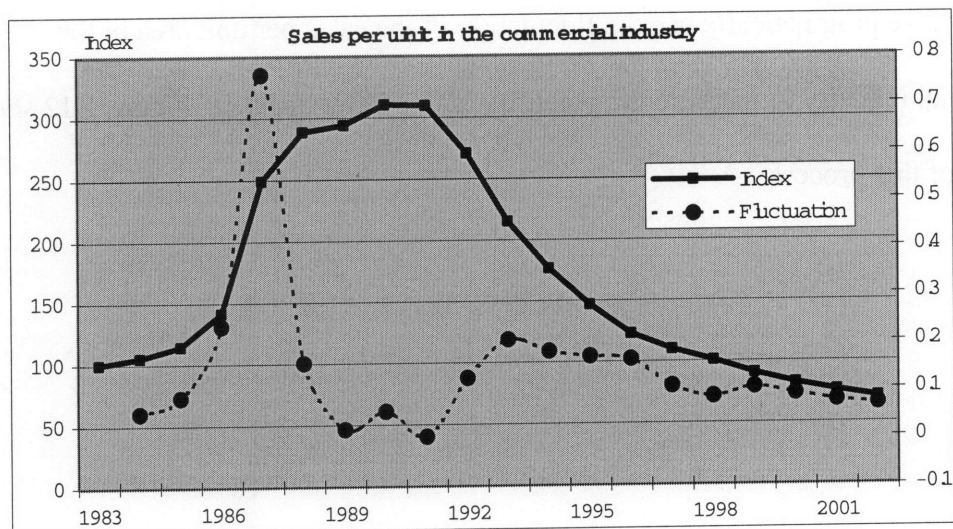


Figure 4-13 Volatility in the sales per unit area

Figure 4-13 indicates the historical data of the sales per unit area in the commercial industries in Japan<sup>39</sup> (index =100 in 1983). The average rate of the annual fluctuations determines the possible range of the movement of an estimate, and consequently measures the volatility of the projects. Although the drastic increase of sales in 1987 (due to the economic boom) seems to be exceptional, similar situations may occur during the long periods (15-20 years) of the projects. Therefore, we consider the past 20 years and include the data from 1987 to determine the volatility in this analysis.

$$\sigma \text{ (volatility)} = 14.4\%$$

Finally, we can value the projects based on the options to wait by using these parameters in spreadsheets (Binominal Models).

### 4.2.3 Options Value

The results of ROV analysis are shown in the table 4-4:

**Table 4-4 Results of ROV analysis**

The value of Project	ROV (w/ wait option)	NPV (w/o options)	ROV-NPV
Project A	\$4.2M	-\$0.7M	\$4.9M
Project B	\$4.9M	-\$0.1M	\$5.0M

<sup>39</sup> [http://www.mizuhocbk.co.jp/pdf/industry/1001\\_18.pdf](http://www.mizuhocbk.co.jp/pdf/industry/1001_18.pdf)

Project C provides options to examine the effectiveness of station development strategy, and make investment decisions in projects A and B. The total value of the projects A and B increases by \$9.9M with the wait options, which are actually almost twice the NPV of project C. We can recognize that project C is more significant as a pilot project than for its cash flows. In this case, project C has positive NPV, so managers can make investment even if they do not recognize the value of options. However, the ROV indicates that managers can invest in project C even if the NPV is slightly negative ( $\text{NPV} + \text{options value} > 0$ ) when they focus on long-term returns from their projects. It depends on the investment policy whether managers invest in a project, which has negative NPV and high options value. However, managers can consider the results of real options analysis to match their decision-makings with the investment strategy.

Here is the structure of the spreadsheets in the case of project A. Based on the given parameters and the Binominal formulas (3.3.2 Binominal Model), we calculate the following numbers, which we use in this analysis.

**Table 4-5 Parameters**

<b>Asset Value (Initial)</b>	<b>S</b>	38.900	\$M
<b>Strike Price</b>	<b>K</b>	39.600	\$M
<b>Risk-free Rate</b>	<b>R</b>	1.5%	
<b>Volatility (year)</b>	<b><math>\sigma</math></b>	14.4%	
<b>Time interval (year)</b>	<b><math>\Delta t</math></b>	1.000	

<b>Up Factor</b>	<b>u</b>	1.155
<b>Down Factor</b>	<b>d</b>	0.866

<b>Up Probability</b>	<b>p</b>	0.516
<b>Down Prob.</b>	<b>1-p</b>	0.484

<b>Discount Factor</b>	<b>DF</b>	0.985
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Note:  $S$ ,  $K$ ,  $r$ ,  $\sigma$ , and  $\Delta t$  = given numbers in 4.2.2 (valuation process)

$$u = e^{\exp(\sigma \sqrt{\Delta t})} = e^{\exp(0.144\sqrt{1})} = 1.155$$

$$d = e^{\exp(-\sigma \sqrt{\Delta t})} = e^{\exp(-0.144\sqrt{1})} = 0.866$$

$$p = (1+r-d)/(u-d) = (1+0.015-0.866)/(1.155-0.866) = 0.516$$

$$DF = e^{\exp(-r \cdot \Delta t)} = e^{\exp(-0.015 \cdot 1)} = 0.985$$

Using these numbers, we can build the spreadsheets as in Table 4-6. The asset value varies based on the volatility (via up and down factors) in each period. The exercise value is the immediate payoff from project A. Managers can invest in project A, and capture the exercise value whenever the situation is favorable to the project. The holding value is the expected value of the project in the next period. Managers have options to invest even in the next period, and can compare the values of exercise and holding, and make a decision as to when they exercise the option to invest in the projects.

Option values (= project value) will be determined by this decision. If managers invest, the option value is equal to the exercise value in the period, while the option value is the holding value in the case of not investing. We can calculate the option value by expanding the same process to the final periods where the holding value is zero due to the expiration. Figure 4-14 is a flow chart, which explains the logic in this model.

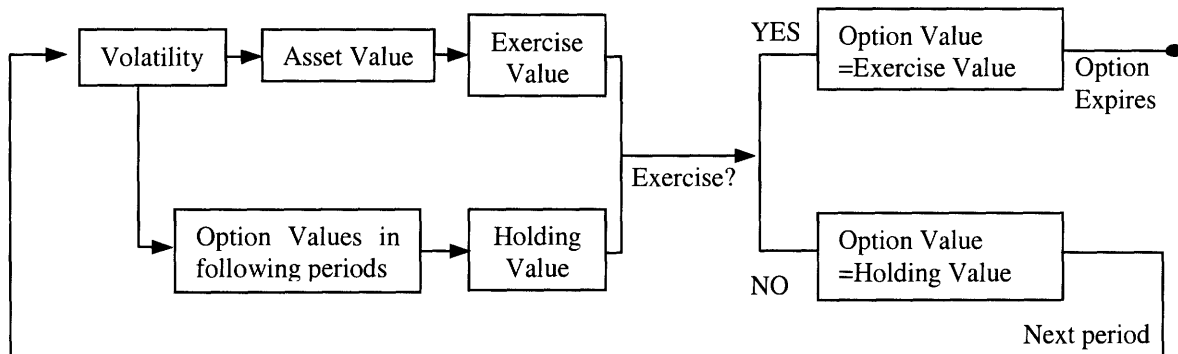
**Table 4-6 Binominal Model of Project A (period 0-1)**

Period	0		1
Asset Value	38.900		44.925
Exercise V.	(0.700)		5.325
Holding V.	4.228		8.232
Option V.	4.228		5.325
Exercise?	NO		YES <sup>40</sup>

Asset Value			33.683
Exercise V.			(5.917)
Holding V.			3.192
Option V.			3.192
Exercise?			NO

(unit: million dollars)



**Figure 4-14 Flow chart for the decision process in exercising options**

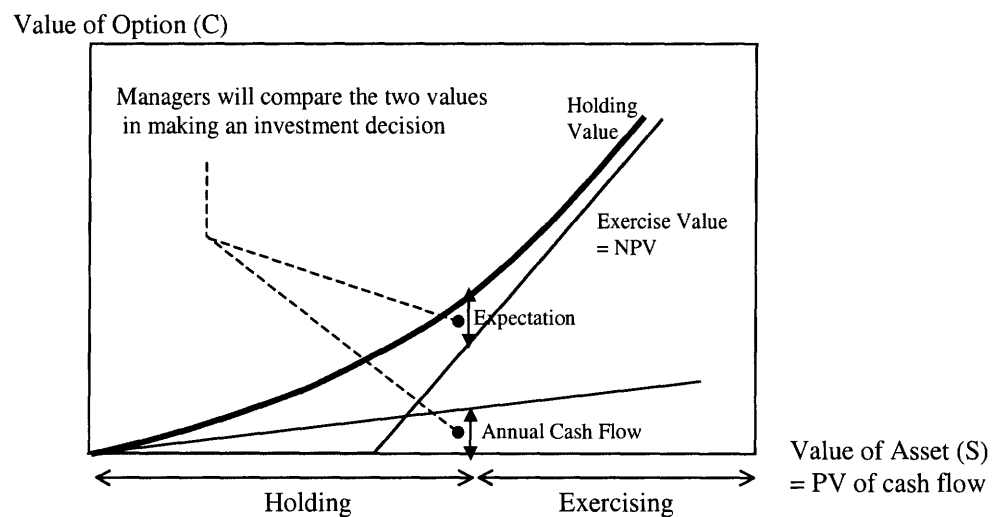
We next have to define the timing of exercising the investment options. Theoretically, managers have to exercise their investment options only when the exercise value exceeds the holding value. If the payoff is sufficiently large, however, they are tempted to exercise the options and capture the benefit. In this analysis, if managers wait for the

<sup>40</sup> The investment option is exercised because the holding value is less than the exercise value plus annual cash flow (\$8.23 < \$5.3M + \$3.69M). Please read the following page for details.



exercise value to exceed the holding value, they cannot invest until the last period<sup>41</sup>. However, managers have to generate cash flows from these projects, and achieve their medium-term business plan by the year of 2006. Therefore, managers can decide to invest when they expect sufficient cash flows to meet their objectives. In projects A and B, we assume that managers exercise their investment options when the future expectation ( $= \text{Holding Value} - \text{Exercise Value}$ ) is less than the annual cash flow in a certain period.

Finally, we obtain the whole spreadsheet through repeating the calculation and decision processes in each period as shown in Table 4-7 and 4-8.



**Figure 4-15 Exercise Timing**

<sup>41</sup> Please compare the values in Table 4-6 and 7

**Table 4-7 Option Pricing for Project A**

Period	0	1	2	3	4	5	6	7
Asset Value	38.900	44.925	51.883	59.919	69.200	79.917	92.295	106.590
Exercise V.	(0.700)	5.325	12.283	20.319	29.600	40.317	52.695	66.990
Holding V.	4.228	8.232	12.867	20.902	30.181	40.898	53.275	67.568
Option V.	4.228	5.325	12.283	20.319	29.600	40.317	52.695	66.990
Exercise?	NO	YES	YES	YES	YES	YES	YES	YES
Asset Value		33.683	38.900	44.925	51.883	59.919	69.200	79.917
Exercise V.		(5.917)	(0.700)	5.325	12.283	20.319	29.600	40.317
Holding V.		3.192	4.171	8.198	12.867	20.902	30.181	40.898
Option V.		3.192	4.171	5.325	12.283	20.319	29.600	40.317
Exercise?		NO	NO	YES	YES	YES	YES	YES
Asset Value			29.166	33.683	38.900	44.925	51.883	59.919
Exercise V.			(10.434)	(5.917)	(0.700)	5.325	12.283	20.319
Holding V.			2.247	3.072	4.099	8.153	12.867	20.902
Option V.			2.247	3.072	4.099	5.325	12.283	20.319
Exercise?			NO	NO	NO	YES	YES	YES
Asset Value				25.254	29.166	33.683	38.900	44.925
Exercise V.				(14.346)	(10.434)	(5.917)	(0.700)	5.325
Holding V.				1.438	2.073	2.920	4.004	8.090
Option V.				1.438	2.073	2.920	4.004	5.325
Exercise?				NO	NO	NO	NO	YES
Asset Value					21.867	25.254	29.166	33.683
Exercise V.					(17.733)	(14.346)	(10.434)	(5.917)
Holding V.					0.805	1.235	1.856	2.721
Option V.					0.805	1.235	1.856	2.721
Exercise?					NO	NO	NO	NO
Asset Value						18.935	21.867	25.254
Exercise V.						(20.665)	(17.733)	(14.346)
Holding V.						0.371	0.612	0.992
Option V.						0.371	0.612	0.992
Exercise?						NO	NO	NO
Asset Value							16.395	18.935
Exercise V.							(23.205)	(20.665)
Holding V.							0.126	0.225
Option V.							0.126	0.225
Exercise?							NO	NO
Asset Value								14.196
Exercise V.								(25.404)
Holding V.								0.024
Option V.								0.024
Exercise?								NO

8	9	10	11	12	13	14	15
123.100	142.166	164.185	189.615	218.983	252.900	292.070	337.307
83.500	102.566	124.585	150.015	179.383	213.300	252.470	297.707
84.076	103.140	125.156	150.583	179.948	213.861	253.027	0.000
83.500	102.566	124.585	150.015	179.383	213.300	252.470	297.707
YES	YES	YES	YES	YES	YES	YES	YES
92.295	106.590	123.100	142.166	164.185	189.615	218.983	252.900
52.695	66.990	83.500	102.566	124.585	150.015	179.383	213.300
53.275	67.568	84.076	103.140	125.156	150.583	179.948	0.000
52.695	66.990	83.500	102.566	124.585	150.015	179.383	213.300
YES	YES	YES	YES	YES	YES	YES	YES
69.200	79.917	92.295	106.590	123.100	142.166	164.185	189.615
29.600	40.317	52.695	66.990	83.500	102.566	124.585	150.015
30.181	40.898	53.275	67.568	84.076	103.140	125.156	0.000
29.600	40.317	52.695	66.990	83.500	102.566	124.585	150.015
YES	YES	YES	YES	YES	YES	YES	YES
51.883	59.919	69.200	79.917	92.295	106.590	123.100	142.166
12.283	20.319	29.600	40.317	52.695	66.990	83.500	102.566
12.867	20.902	30.181	40.898	53.275	67.568	84.076	0.000
12.283	20.319	29.600	40.317	52.695	66.990	83.500	102.566
YES	YES	YES	YES	YES	YES	YES	YES
38.900	44.925	51.883	59.919	69.200	79.917	92.295	106.590
(0.700)	5.325	12.283	20.319	29.600	40.317	52.695	66.990
3.873	7.998	12.867	20.902	30.181	40.898	53.275	0.000
3.873	5.325	12.283	20.319	29.600	40.317	52.695	66.990
NO	YES	YES	YES	YES	YES	YES	YES
29.166	33.683	38.900	44.925	51.883	59.919	69.200	79.917
(10.434)	(5.917)	(0.700)	5.325	12.283	20.319	29.600	40.317
1.577	2.447	3.681	7.847	12.867	20.902	30.181	0.000
1.577	2.447	3.681	5.325	12.283	20.319	29.600	40.317
NO	NO	NO	YES	YES	YES	YES	YES
21.867	25.254	29.166	33.683	38.900	44.925	51.883	59.919
(17.733)	(14.346)	(10.434)	(5.917)	(0.700)	5.325	12.283	20.319
0.400	0.700	1.208	2.043	3.363	7.534	12.867	0.000
0.400	0.700	1.208	2.043	3.363	5.325	12.283	20.319
NO	NO	NO	NO	NO	YES	YES	YES
16.395	18.935	21.867	25.254	29.166	33.683	38.900	44.925
(23.205)	(20.665)	(17.733)	(14.346)	(10.434)	(5.917)	(0.700)	5.325
0.047	0.092	0.181	0.355	0.699	1.376	2.707	0.000
0.047	0.092	0.181	0.355	0.699	1.376	2.707	5.325
NO	NO	NO	NO	NO	NO	NO	YES
12.293	14.196	16.395	18.935	21.867	25.254	29.166	33.683
(27.307)	(25.404)	(23.205)	(20.665)	(17.733)	(14.346)	(10.434)	(5.917)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NO	NO	NO	NO	NO	NO	NO	NO
	10.644	12.293	14.196	16.395	18.935	21.867	25.254
	(28.956)	(27.307)	(25.404)	(23.205)	(20.665)	(17.733)	(14.346)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	NO	NO	NO	NO	NO	NO	NO
		9.216	10.644	12.293	14.196	16.395	18.935
		(30.384)	(28.956)	(27.307)	(25.404)	(23.205)	(20.665)
		0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000
		NO	NO	NO	NO	NO	NO
			7.980	9.216	10.644	12.293	14.196
			(31.620)	(30.384)	(28.956)	(27.307)	(25.404)
			0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000
			NO	NO	NO	NO	NO
				6.910	7.980	9.216	10.644
				(32.690)	(31.620)	(30.384)	(28.956)
				0.000	0.000	0.000	0.000
				0.000	0.000	0.000	0.000
				NO	NO	NO	NO
					5.983	6.910	7.980
					(33.617)	(32.690)	(31.620)
					0.000	0.000	0.000
					0.000	0.000	0.000

**Table 4-8 Option Pricing for Project B**

Period	0	1	2	3	4	5	6	7
Asset Value	40.610	46.900	54.164	62.553	72.241	83.431	96.353	111.276
Exercise V.	(0.090)	6.200	13.464	21.853	31.541	42.731	55.653	70.576
Holding V.	4.923	9.159	14.064	22.452	32.139	43.327	56.248	71.170
Option V.	4.923	6.200	13.464	21.853	31.541	42.731	55.653	70.576
Exercise?	NO	YES	YES	YES	YES	YES	YES	YES
Asset Value		35.164	40.610	46.900	54.164	62.553	72.241	83.431
Exercise V.		(5.536)	(0.090)	6.200	13.464	21.853	31.541	42.731
Holding V.		3.716	4.857	9.119	14.064	22.452	32.139	43.327
Option V.		3.716	4.857	6.200	13.464	21.853	31.541	42.731
Exercise?		NO	NO	YES	YES	YES	YES	YES
Asset Value			30.448	35.164	40.610	46.900	54.164	62.553
Exercise V.			(10.252)	(5.536)	(0.090)	6.200	13.464	21.853
Holding V.			2.616	3.577	4.772	9.066	14.064	22.452
Option V.			2.616	3.577	4.772	6.200	13.464	21.853
Exercise?			NO	NO	NO	YES	YES	YES
Asset Value				26.364	30.448	35.164	40.610	46.900
Exercise V.				(14.336)	(10.252)	(5.536)	(0.090)	6.200
Holding V.				1.674	2.414	3.400	4.662	8.994
Option V.				1.674	2.414	3.400	4.662	6.200
Exercise?				NO	NO	NO	NO	YES
Asset Value					22.829	26.364	30.448	35.164
Exercise V.					(17.871)	(14.336)	(10.252)	(5.536)
Holding V.					0.937	1.438	2.161	3.168
Option V.					0.937	1.438	2.161	3.168
Exercise?					NO	NO	NO	NO
Asset Value						19.767	22.829	26.364
Exercise V.						(20.933)	(17.871)	(14.336)
Holding V.						0.432	0.712	1.155
Option V.						0.432	0.712	1.155
Exercise?						NO	NO	NO
Asset Value							17.116	19.767
Exercise V.							(23.584)	(20.933)
Holding V.							0.147	0.262
Option V.							0.147	0.262
Exercise?							NO	NO
Asset Value								14.821
Exercise V.								(25.879)
Holding V.								0.028
Option V.								0.028
Exercise?								NO

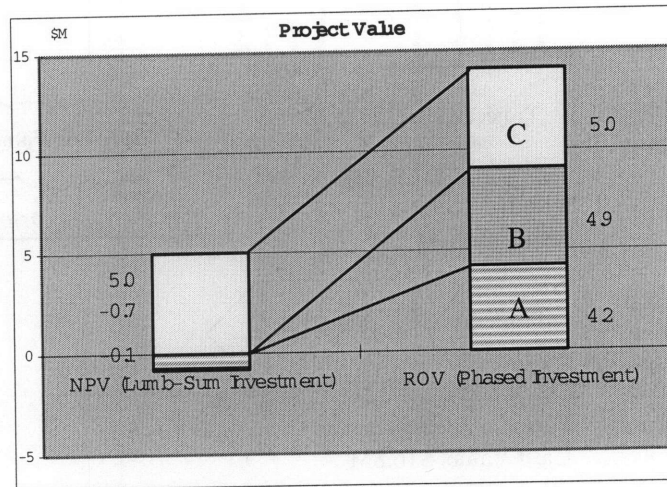
8	9	10	11	12	13	14	15
128.511	148.415	171.402	197.950	228.609	264.017	304.909	352.135
87.811	107.715	130.702	157.250	187.909	223.317	264.209	311.435
88.403	108.305	131.289	157.834	188.490	223.894	264.781	0.000
87.811	107.715	130.702	157.250	187.909	223.317	264.209	311.435
YES	YES	YES	YES	YES	YES	YES	YES
96.353	111.276	128.511	148.415	171.402	197.950	228.609	264.017
55.653	70.576	87.811	107.715	130.702	157.250	187.909	223.317
56.248	71.170	88.403	108.305	131.289	157.834	188.490	0.000
55.653	70.576	87.811	107.715	130.702	157.250	187.909	223.317
YES	YES	YES	YES	YES	YES	YES	YES
72.241	83.431	96.353	111.276	128.511	148.415	171.402	197.950
31.541	42.731	55.653	70.576	87.811	107.715	130.702	157.250
32.139	43.327	56.248	71.170	88.403	108.305	131.289	0.000
31.541	42.731	55.653	70.576	87.811	107.715	130.702	157.250
YES	YES	YES	YES	YES	YES	YES	YES
54.164	62.553	72.241	83.431	96.353	111.276	128.511	148.415
13.464	21.853	31.541	42.731	55.653	70.576	87.811	107.715
14.064	22.452	32.139	43.327	56.248	71.170	88.403	0.000
13.464	21.853	31.541	42.731	55.653	70.576	87.811	107.715
YES	YES	YES	YES	YES	YES	YES	YES
40.610	46.900	54.164	62.553	72.241	83.431	96.353	111.276
(0.090)	6.200	13.464	21.853	31.541	42.731	55.653	70.576
4.510	8.887	14.064	22.452	32.139	43.327	56.248	0.000
4.510	6.200	13.464	21.853	31.541	42.731	55.653	70.576
NO	YES	YES	YES	YES	YES	YES	YES
30.448	35.164	40.610	46.900	54.164	62.553	72.241	83.431
(10.252)	(5.536)	(0.090)	6.200	13.464	21.853	31.541	42.731
1.837	2.849	4.285	8.710	14.064	22.452	32.139	0.000
1.837	2.849	4.285	6.200	13.464	21.853	31.541	42.731
NO	NO	NO	YES	YES	YES	YES	YES
22.829	26.364	30.448	35.164	40.610	46.900	54.164	62.553
(17.871)	(14.336)	(10.252)	(5.536)	(0.090)	6.200	13.464	21.853
0.465	0.815	1.406	2.378	3.915	8.346	14.064	0.000
0.465	0.815	1.406	2.378	3.915	6.200	13.464	21.853
NO	NO	NO	NO	NO	YES	YES	YES
17.116	19.767	22.829	26.364	30.448	35.164	40.610	46.900
(23.584)	(20.933)	(17.871)	(14.336)	(10.252)	(5.536)	(0.090)	6.200
0.054	0.107	0.210	0.414	0.814	1.602	3.151	0.000
0.054	0.107	0.210	0.414	0.814	1.602	3.151	6.200
NO	NO	NO	NO	NO	NO	NO	YES
12.833	14.821	17.116	19.767	22.829	26.364	30.448	35.164
(27.867)	(25.879)	(23.584)	(20.933)	(17.871)	(14.336)	(10.252)	(5.536)
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NO	NO	NO	NO	NO	NO	NO	NO
	11.112	12.833	14.821	17.116	19.767	22.829	26.364
	(29.588)	(27.867)	(25.879)	(23.584)	(20.933)	(17.871)	(14.336)
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	NO	NO	NO	NO	NO	NO	NO
		9.622	11.112	12.833	14.821	17.116	19.767
		(31.078)	(29.588)	(27.867)	(25.879)	(23.584)	(20.933)
		0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000
		NO	NO	NO	NO	NO	NO
			8.331	9.622	11.112	12.833	14.821
			(32.369)	(31.078)	(29.588)	(27.867)	(25.879)
			0.000	0.000	0.000	0.000	0.000
			0.000	0.000	0.000	0.000	0.000
			NO	NO	NO	NO	NO
				7.214	8.331	9.622	11.112
				(33.486)	(32.369)	(31.078)	(29.588)
				0.000	0.000	0.000	0.000
				0.000	0.000	0.000	0.000
				NO	NO	NO	NO
					6.246	7.214	8.331
					(34.454)	(33.486)	(32.369)
					0.000	0.000	0.000
					0.000	0.000	0.000

## 4.3 Recommendations

### 1. Recognize the value of wait options, and make phased investment

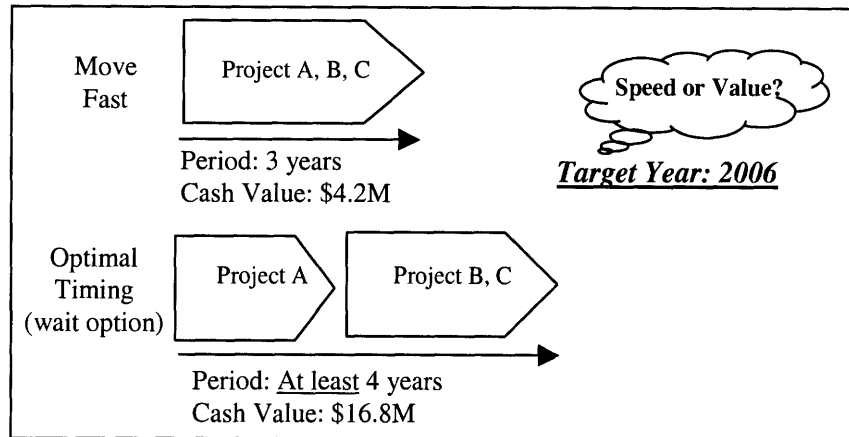
It is not a wise strategy to invest in the three projects at the same time; or rather, managers should launch only project C as a pilot case. They can expect about \$5.0M NPV from the investment, and acquire options to wait and see the results of their strategy, which are worth \$9.9M in total. Managers can examine the reaction from customers in project C, and make decisions on projects A and B based on it.

It is risky to invest in a large project under uncertainty. If the project turns out in failure, the negative impact can be serious to JR East. Therefore, it is essential to make phased investment, and limit the potential loss of this project while holding options to make the rest of the investment. Thus, phased investment provides us with flexibility to cope with uncertainty about the project. The value of this flexibility critically increases the whole value of a large-scale investment under uncertainty. Figure 4-16 shows how the same project has different value according to its implementation strategy. We can appreciate the role of flexibility and importance of phased investment in a strategic project. The ROV is an effective tool to reveal these values, which we could not recognize in the NPV analysis.



**Figure 4-16 Value of the projects (A, B, C) by implementation strategies**

It seems clear that we can benefit from the phased investment if the option is free. However, waiting options actually cost because of the time constraints of their implementation strategy. As we described in the company information, a station development project is one of the main strategies of JR East to achieve its medium-term business plan by 2006. Therefore, it is essential for managers to move fast while trying to find the optimal investment timing, which maximizes the values of project. Managers could not rationally solve the trade-off problem with the NPV analysis, but the ROV clearly provides quantified benchmarks for this strategic decision based on the value of wait options. If the additional value of the projects is worth waiting for, managers should make phased investment; otherwise they can invest in all three projects at the same time.



**Figure 4-17 Managers can choose either speed or cash values in an implement strategy**

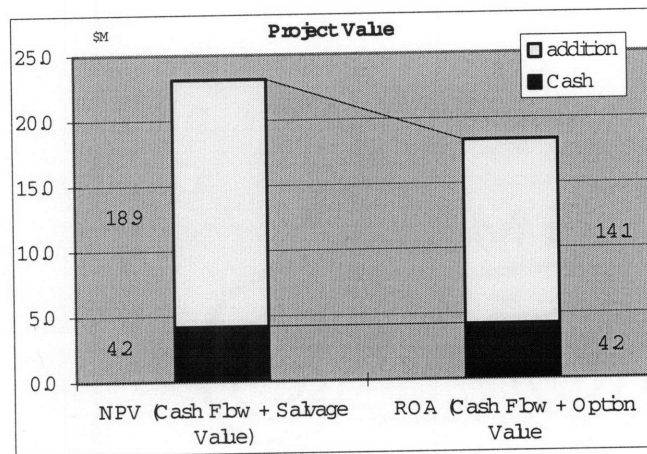
## **2. Recognize the value of options to quantify the expectations.**

In the NPV analysis, managers assumed salvage values in project A and B so as to provide positive NPVs and support their decisions to invest in the projects. They modified the NPVs because this method could not fully explain the values of projects, which experienced managers intuitively recognized.

The ROV provides a clear answer to this vague expectation. That is an “option” to expand their project, and generate incremental cash flows in follow-on projects. Since the company has an additional 27 potential projects in the target area, the cumulative benefit from these projects is so significant that the initial projects are more important as pioneers of this strategic investment than as cash flows.



Although we recommend making phased investments, the company may choose to invest in all three projects at the same time, and move fast to achieve their business plan. In this case, managers have to recognize the value of expansion options, which can be created by the three projects. At this time, we do not have enough information to value the other 27 projects. If we assume, however, that each project creates an option to later invest in a similar project in terms of its scale and area, the value of the options is close to the total amount of the salvage values in the NPV analysis (Figure 4-18). Managers should try to estimate the value of follow-on projects, consider the value of expansion options, and justify the rationale for their investment decisions not with an exceptional method (salvage value) but with consistent analysis (ROV). Managers have to apply an appropriate tool, which can effectively explain their thinking.



**Figure 4-18 Additional Values of Projects**

Although the ROV uses some assumptions to determine the value of investment options, this approach reflects the strategic value of projects, which managers are now considering under uncertainty. Therefore, we recommend them to use the ROV and strategically think in capital investment in transportation systems based on the discussions and case study in this research, which we summarize in next chapter.

## Chapter 5 Conclusion

In this thesis, we examined decision analysis methods of capital investment in transportation systems. The business trend, which regards cash flows as an important criterion of a corporate performance, forces managers to maximize the cash value of a project to meet the shareholder's expectations. The characteristics of transportation systems, however, require a comprehensive approach to optimize the performance over time, and thus, managers need to apply an appropriate tool to measure the value of a project to effectively develop the systems. Here are the conclusions of this research.

### 5.1 Conclusions

Conclusion 1: The strategic value of a project is critical for developing transportation systems.

Focusing on the NPV of a project does not necessarily result in the optimal investment for developing transportation systems. The fundamental nature of CLIOS<sup>42</sup> makes it difficult to fully predict the performance and impacts of a project in transportation systems. Therefore, managers need to recognize the strategic value of a project and create options in addition to the NPV in their investment activities so as to flexibly adjust to unexpected events in the future.

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<sup>42</sup> CLIOS : complex, large, integrated open systems.  
from Sussman, Joseph "Introduction to Transportation Systems", 2000, pp. 6-7

Applying Porter's model and System Dynamics<sup>43</sup> to the railway business, we can recognize the importance of capital investment, which contributes to long-term profitability in the competitive market. The capital investments are, however, typically located in the risky segments of the project portfolio in a railway company, so the investment activities often create unexpected system results. Therefore, managers are required to think strategically so that they can capture the present benefit while enhancing opportunities and avoiding negative results under uncertainty.

Conclusion 2: Real options value (ROV) is an effective tool to measure the strategic value of a project.

Combining the NPV with another method (e.g., decision tree) measures the cash value of a project, and provides benchmarks in investment decisions when the future is fairly stable or probabilistically predictable. However, these methods are insufficient for valuing a project under uncertainty where the potential outcomes are not probabilistically understood, and the estimated value of the strategic options becomes critical to making an investment decision. The ROV clearly values the options, and provides the strategic value of a project under uncertainty.

It is useful to be aware of the merits and limitations of each valuation method. In this sense, the merit of ROV successfully overcomes the limitation of other methods that we reviewed in this thesis. Previously, even if managers recognized the strategic value of a

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<sup>43</sup> 1.2.2 Market Force & 1.2.3 Business Dynamics

project, they did not have an effective tool to quantify their intuitive judgment. Using the realistic evaluation tool can guide managers toward exploiting the opportunities, and creating competitive advantages in the market.

Conclusion 3: The ROV is applicable to transportation systems, and the Binominal Model is a practical tool to measure the ROV in a project.

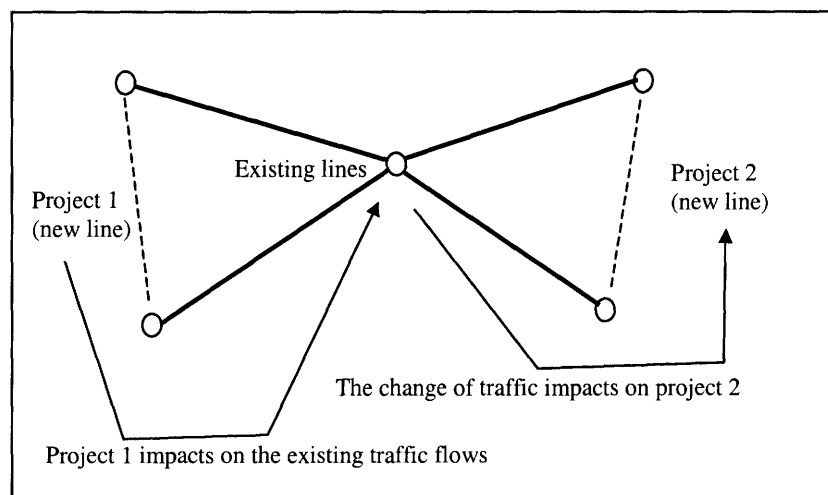
We verified the theoretical correctness of the ROV as applied to transportation systems by proposing the complete market assumption where we can trade options. This complete market enables us to use the no-arbitrage approach, which is an underlying concept of the options pricing theory. We also demonstrated the practicality of ROV and the binominal model through a case study of a railway project, and showed substantial improvements in the investment strategy.

The ROV quantifies the strategic value of a project, and consequently improves the investment strategy. We can increase the value of a project by recognizing the importance of options, looking for opportunities to build them into a project, doing the valuation, and making a “strategic” decision. This approach is critically effective when uncertainty is a major concern, and sequential decisions play an important role in managing a project. Thus, the ROV is quite useful to create a strategic decision in transportation systems.

## 5.2 Future research

We also suggest additional research to apply real options to transportation systems based on the results of this research.

First, we have to consider the role of the “network” in a system, and expand the option-based investment strategy to the portfolio management. This thesis focused on an individual project in applying the ROV to transportation systems. However, the network is a key concept when we study an investment strategy in transportation systems. Individual projects do not work effectively by themselves; rather, they affect each other and develop into integrated systems as a whole. One investment may have side effects and have impacts on the value of another project in the transportation network, and we need to examine the role of this factor as it affects strategic decision-makings.



**Figure 5-1 Network Factor**

Based on the understanding of this factor, we need to investigate how we can value the portfolio of investment options and how the value changes according to investment decisions under uncertainty. The result of this work allows managers to make decisions not only on the project level but also on the corporate level. Just as financial managers build a portfolio of securities to manage risks and benefits of their investment, this approach gives us substantial improvements in managing the corporate strategies in the transportation field.

Next, we need to examine the past transportation projects and create a database and application to use the ROV in practice. In this thesis, we applied the ROV in a railway project. However, we simplified the analysis to avoid the complexity and to emphasize the comparison between the ROV and conventional methods. For instance, volatility will not be determined by a single factor; rather, we need to combine several factors. To make the analysis more realistic and practical, we have to review past railway projects, examine the historical data, and build models and applications, which managers can practically use to make an investment decision.

As we discussed in this thesis, experienced managers intuitively use option thinking to some extent in valuing a project. The ROV offers a way to quantify the intuitive management with a coherent process that more closely approximates the real-world behavior in a dynamic environment.

This thesis helps to improve the investment strategy in the transportation industry. Options theory caused drastic changes in the financial market by providing numerous ways for individuals and corporations to hedge risks and improved the performance of their portfolios. Using real options has further potential to innovate in managing an investment in the fast-moving world of technology and today's uncertain business climate. Managers have to appreciate the benefit of this strategic approach to a project, and the application of real options to transportation systems including railway systems leads real benefit. "Real options are real."<sup>44</sup>

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<sup>44</sup> Tom Copeland, 15.975. SSIM-Real Options-, April 7. 2003



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